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ORIGINAL ARTICLES.

Extensions of the Monteregian Petrographical Province to the West and North-West.

By J. Stansfield, M.A., M.Sc.

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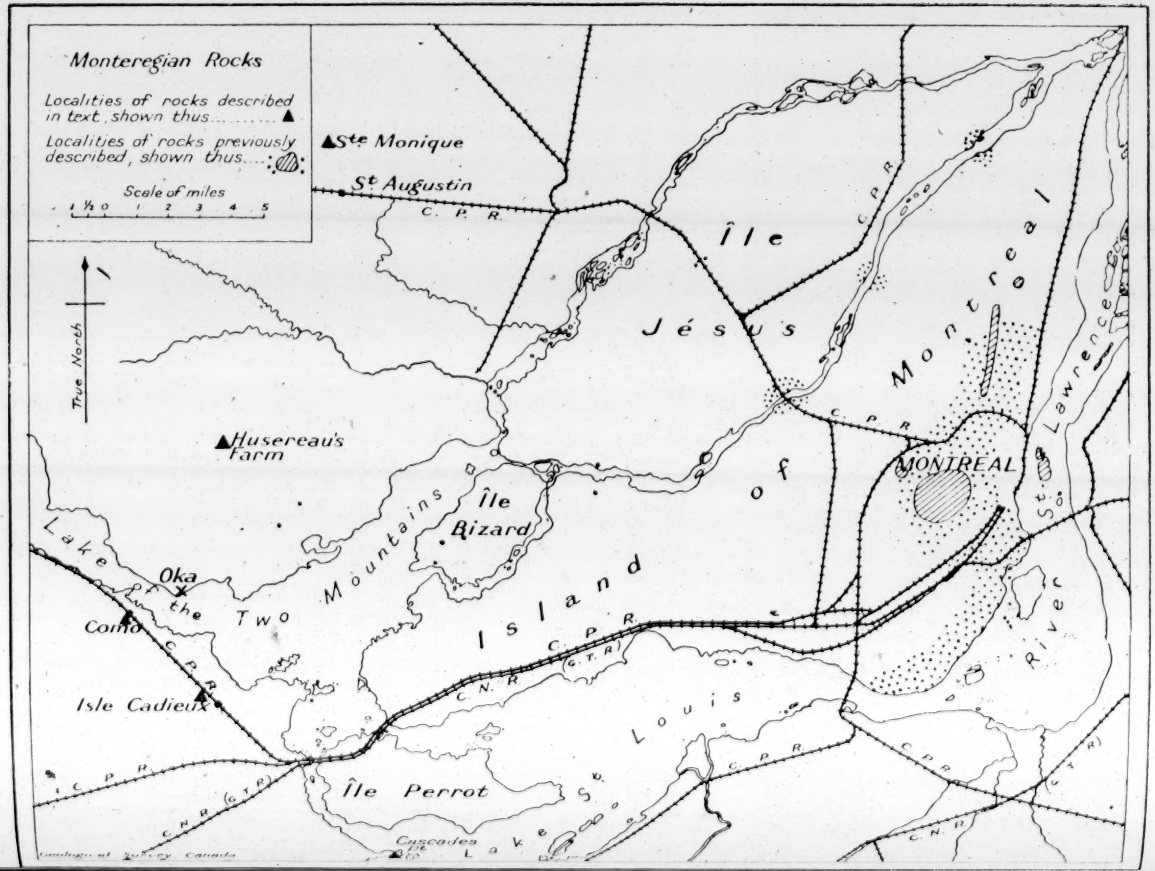
Introduction.

THE occurrences herein described have been brought to light as a result of the work of the Road Materials Division of the Geological Survey of Canada. Those at Ste. Monique and at Husereau's Farm, near Oka, were discovered by Mr. H. Gauthier in 1916 (1),[1] and those at Isle Cadieux, Como and Cascades Point were discovered by Mr. R. H. Picher in the same year (2). It is owing to the kindness and courtesy of Mr. William McInnes, at that time directing geologist of the Geological Survey of Canada, and of Dr. L. Reinecke, at that time chief of the Road Materials Division of the Geological Survey of Canada, that the writer has been given the opportunity of studying these rocks.

The map (Fig. 1) shows the localities at which these discoveries of rocks have been made, and illustrates the way in which the limits of the Monteregian petrographical province are thus enlarged toward the west and north-west. It is a matter of great interest that these newly found occurrences include types either new to or rare in this petrographical province, and two types new to science. The Ste. Monique, Isle Cadieux, Como, and Cascades Point rocks are alnoites, and the rocks at Husereau's farm are the new rock types okaite and nepheline-okaite, and associated with them is a monticellite-alnoite of a type hitherto undescribed.

The alnoite of Isle Cadieux has been described in greater detail than herein by N. L. Bowen (15), and at a date subsequent to the writing of the first part of this paper, of which the publication has been very much delayed. This paper was read, in part, at the 1919 meeting of the Royal Society of Canada, but was not published owing to the fact that the analyses had not been completed.

[1] Figures in parentheses refer to Bibliography at end of paper.


Monteregian Rocks
Localities of rocks described in text, shown thus.....▲
Localities of rocks previously described, shown thus.....
Scale of miles
1 ½ 0 1 2 3 4 5
True North
▲Ste Monique
St Augustin
C. P. R.
Île Jésus
C P R
Montreal
St. Lawrence River
▲Husereau's Farm
Île Bizard
MONTREAL
Lake of the Two Mountains
Island of
Oka
Como
Isle Cadieux
C P R
C N R (G T R)
Île Perrot
Cascades
Lake St. Louis

It is owing to the kindness of the British Scientific and Industrial Research Department that the analyses have been carried out by the Geological Survey of Great Britain. The writer wishes to express his best thanks for this valuable aid, and to Dr. J. S. Flett, Director of the Geological Survey of Great Britain, for his personal interest in the work, and to the staff of the Mineralogical Department of the British Museum (Natural History), especially Mr. W. Campbell Smith, for help in the determination of physical constants of minerals in the okaites.

Howard (16) has recently described most of the rocks discussed herein, most of them under other names.

Single specimens were available to the writer, in each case except the Husereau farm locality. This accounts for the absence, in his record, of augite, brookite (?), and monticellite in the Ste. Monique alnoite, and monticellite in the Isle Cadieux alnoite. The absence of apatite in the two specimens from Isle Cadieux and Ste. Monique is to be regarded as illustrating the very marked variability from point to point in the rocks, of this constituent, which is very rarely absent from alnoites and is often abundant in them.

With regard to other discrepancies between the writer's account and Howard's, part of them may be put down to variability of these rocks, which is quite marked, part to his examination of altered material (camptonite (Howard), monticellite-alnoite (Stansfield) of Husereau farm), and part to inclusion of melilite under the head of monticellite (Ste. Monique), or under the head of nepheline (camptonite (Howard) and nepheline-aplite (Howard) of Husereau farm).

The Alnoites.

Rocks of this type have been found at four localities: Ste. Monique, Isle Cadieux, Como, and Cascades Point, all within a distance of 30 miles west, south-west, or north-west of Montreal.

The alnoite at Ste. Monique is exposed on flat-topped hills which are slightly higher than the surrounding plain, no contacts with the Palæozoic sediments underlying the plain being visible. The flat-topped hills lie directly (100 yards or so) north of the village. The others are found by following the road north from Ste. Monique for about a mile, one occurrence being found west of the road, and the other, and largest, to the east of the road.

At Isle Cadieux the alnoite occurs on a small conspicuous hill on the west side of the Canadian Pacific railway, half a mile west of Isle Cadieux station. It is surrounded by a flat area in which the surface materials are drift, so that no contacts with the Palæozoic sediments are to be seen.

The alnoite at Como occurs as loose boulders lying on a small hill about 200 yards west of the Canadian Pacific railway at a point three-quarters of a mile south-east of Como station. It is possible that an outcrop may be discovered immediately beneath, if search were made. The surrounding plain is covered by drift.

The alnoite at Cascades Point occurs as a dike 6 inches wide, cutting Potsdam sandstone, in Brunel's quarry. The dike is approximately vertical. (No hand specimen available.)

Macroscopical Characters.

The Ste. Monique rock is dark grey, almost black in colour, coarse and fine grained varieties being recognizable. The coarse-grained variety, by reason of the crystalline continuity of the mica individuals over spaces up to a quarter of an inch in diameter, approaches the appearance of some peridotites. Close examination shows the interstitial matter to be fine-grained, and in it are occasional phenocrysts of olivine of an almost black colour. The fine-grained variety shows the characters of the interstitial matter of the rock just described. In it are a few phenocrysts of olivine, but the mica does not show prominently. This fine-grained variety has the appearance of a quickly cooled, hypabyssal rock, or of a holocrystalline basalt. (This variety has characters which place it close to monchiquite.)

The alnoite of Isle Cadieux is very similar to the coarser variety from Ste. Monique, and nothing needs to be added to that description except that, away from their field occurrences, it would be practically impossible to distinguish them in hand specimens.

The Como alnoite is finer-grained than the last-mentioned. It has a similar colour, the distinguishing feature being that the micas do not reach such a large size, one-sixteenth to one-tenth of an inch in greater diameter being the rule. This rock may be distinguished from the others described by the size of its mica individuals. The appearance of this rock is that characteristic of fine-grained alnoites, at least as found in the Monteregian petrographical province.

Microscopical Characters.

The coarse-grained alnoite of Ste. Monique and the alnoites from Isle Cadieux and Como possess such similar microscopical characters that one may be described as typical of the three. The outstanding feature possessed by these three alnoites, in common, is their extreme freshness. The writer is not acquainted with any alnoite which is at all comparable with these as regards freshness. The olivine and melilite are very rarely altered, and then only very slightly, secondary minerals being almost entirely absent.

The coarse-grained alnoite of Ste. Monique is composed of the following minerals, in the order of their importance: olivine, melilite, bleached biotite, and accessory iron ore, perovskite, and calcite.

The olivine makes up the greater part of the rock and occurs as porphyritic crystals of small size, with a few larger ones. It is remarkably fresh, showing no serpentinization. The melilite, which has a faintly brownish tint, fills in spaces between the olivine crystals. In general, it does not show a tendency toward idiomorphic

outlines. It encloses iron ore and perovskite. Some parts of it show a very feeble birefringence so as to be almost isotropic, whereas other portions show a birefringence about the same as that of nepheline. Within this latter are patches of irregular shape which are isotropic. "Peg structure" is only occasionally seen, unless the last-mentioned feature indicate this structure on a larger scale than is usual. (Not being able to refer to the specimens of this rock, the presence of monticellite in it is left an open question. If present, it has been included by the writer with the melilite.) The mica is usually poikilitic to olivine, which accounts for its apparent importance in the hand specimen. It is faintly pleochroic, and not unlike phlogopite, though partial bleaching of biotite could give rise to a similar mica. There are occasional idiomorphic flakes of the mica. Perovskite, in well-formed octahedra, is abundant, as is also a black iron ore. The olivine has some inclusions of the iron ore, but in the main the olivine crystallized first, followed by iron ore and perovskite, and these by mica and then melilite. Secondary calcite is present in very small amount, having been formed at the expense of melilite. In some places the melilite is altered to a radially-arranged, probably zeolitic mineral, not unlike prehnite, though this is rare also. Some of the interstitial calcite encloses iron ore and perovskite. This is regarded as primary calcite, which was the last of the primary minerals to be formed.

In the Isle Cadieux alnoite the olivine is prominent in amount, and some of it shows incipient alteration with the production of broad, irregular, dark bands of magnetite dust across the crystals. There is no serpentine. Part of the mica is strongly pleochroic, but most of it is faintly pleochroic, which suggests that the mica is a biotite which has been bleached. A small amount of a colourless augite is present, occurring as small porphyritic crystals. An extinction angle of 43° was observed. Secondary calcite and the possible prehnite are present in small amount. Primary calcite is more abundant than in the Ste. Monique rock. It encloses iron ore and perovskite, and also idiomorphic stumpy laths of melilite. Idiomorphic mica flakes are also seen to cut through calcite, and in some cases through augite. The melilite is not quite so abundant as in the Ste. Monique rock. It usually shows no crystal outline and feeble birefringence, though occasionally the birefringence reaches near to that of felspars. Very occasionally laths of a more stumpy character than is usual with melilite are enclosed in the mica. Occasionally some parts of a melilite individual are isotropic, while other parts, in crystalline continuity, show double refraction. The melilite shows more alteration than in the Ste. Monique rock. The change is to a fibrous mineral, possibly prehnite.

In the Como alnoite, incipient alteration of the olivine has only gone so far as the production of bands of magnetite dust through the crystals, without the formation of serpentine. The mica is

strongly pleochroic, part of it being bleached. It may be referred to biotite. A very faintly brown augite is present. Primary calcite, enclosing iron ore and perovskite, is more abundant than in the two preceding rocks. There are also a few needles of apatite which may be enclosed in augite or olivine. A colourless mineral occurs interstitially. It is seen, in some cases, in optical continuity with olivine possessing idiomorphic outlines. It has a slightly lower refractive index, but a much lower birefringence than the first crop olivine. It may be regarded as a second or subsequent crystallization of olivine. (This is the mineral identified by Scheumann (18) and Bowen (15) as monticellite.) The melilite shows a greater tendency to idiomorphic outlines than in the rocks described above, though most of it is hypidiomorphic and interstitial. Laths of it are sometimes enclosed in the mica. Alteration similar to that noted in the case of the Isle Cadieux rock has taken place, much of the melilite having a dusty appearance, as a result.

Cascades Point.

This alnoite is not so fresh as the ones described above. The olivine occurs as porphyritic crystals of small size, which are largely altered to carbonates and a greenish serpentine, which shows the full birefringence of that mineral.

Melilite laths altered to calcite are prominent, only a few remaining unaltered. Their length is usually many times their breadth. They often occur, arranged tangentially to the altered olivines, as "coronas". The altered melilite laths are contained in a ground consisting of almost completely bleached biotite scales and calcite (perhaps with other carbonates). Carbonates make up much of the rock and fill many large clear spaces, as well as being disseminated through the groundmass. Iron ore and perovskite are present in notable amount, though always accessory. Where not altered, the melilite is colourless. In some parts the birefringence is low, but in other parts of the rock it is higher than is usual for this mineral.

Chemical Analyses.

Chemical analyses of three varieties of the Isle Cadieux alnoite have been made by H. S. Washington in connexion with the studies made by Bowen (15). Since the alnoites of Ste. Monique, Isle Cadieux, and Como are so very similar, duplication of the work of analysis is not called for. Two of Washington's analyses are reproduced below. I is a monticellite-alnoite (melilite-poor), which is selected as being representative for the three localities mentioned. II is the analysis of a melilite-biotite rock, a variety of the Isle Cadieux rock found and described by Bowen. It is included here for the sake of easy comparison with the other accompanying analyses. Analyses of the Como and Ste. Monique alnoites (the latter under the name of monchiquite) have been

made by Howard. They are reproduced here under V and VI respectively :—

	I	V	VI	II	III	IV
SiO_2 .	30·85	30·27	31·63	31·10	30·13	31·37
TiO_2 .	2·87	2·84	2·44	2·73	2·38	2·00
Al_2O_3 .	8·21	10·00	10·60	10·08	11·02	15·16
Fe_2O_3 .	3·33	4·88	4·56	3·64	7·34	4·94
FeO .	6·52	6·95	6·42	3·35	4·17	3·46
MnO .	·21	·16	·11	·09	·52	·51
(CoNi)O	—	—	—	—	·05	—
CaO .	16·46	14·73	17·16	22·77	22·48	27·10
BaO .	—	—	—	—	·89	·16
MgO .	23·16	20·11	17·82	12·25	12·01	4·77
K_2O .	1·43	2·85	2·48	3·56	2·07	1·06
Na_2O .	1·01	1·49	·61	1·95	1·43	4·55
Li_2O .	—	—	—	—	—	tr.
H_2O —	·05	—	—	·46	·13	·04
H_2O +	1·22	2·17	·93	·76	·82	·83
P_2O_5	1·90	·95	1·09	2·01	2·88	1·66
FeS_2 .	—	—	—	—	·13	·21
Fe_7S_8 .	—	—	—	—	·32	·13
SO_3 .	—	—	—	—	·11	·35
CO_2 .	3·04	3·24	4·92	4·94	1·17	1·74
Cl .	—	—	—	—	tr.	·04
Total .	100·26	100·64	100·77	99·69	100·05	100·08

Norms of III *and* IV	III	IV
an .	17·79	17·93
ne .	6·25	19·88
kp .	6·95	3·79
th .	·14	·64
C .	—	·20
ol .	20·30	8·40
cs .	20·47	29·24
di .	2·38	—
mt .	9·28	5·80
il .	2·74	3·80
hm .	·96	·96
ap .	6·72	4·03
pr .	·84	·60
cc .	2·70	4·00

I. Monticellite-alnoite (melilite-poor). Isle Cadieux, Quebec. H. S. Washington.
II. Melilite-biotite rock. Isle Cadieux, Quebec. H. S. Washington.
III. Monticellite-alnoite. Husereau's farm, near Oka, Quebec. Symbol: IV, 2 (5), 3 (2), 3. F. R. Ennos.
IV. Nepheline-okaite. Husereau's farm, near Oka, Quebec. Symbol: III, 7, 3 (4), 2. F. R. Ennos.
V. Monticellite-alnoite. Como, Quebec. W. V. Howard.
VI. Alnoite (Monchiquite of Howard). Ste. Monique, Quebec. W. V. Howard.

Monchiquitic Facies of Alnoite.

The fine-grained variety of the Ste. Monique rock shows characters which place it close to the monchiquites. Under the microscope its characters are practically identical with those of the coarse-grained alnoite as regards the olivine, bleached biotite, primary calcite, iron ore, and perovskite.

The spaces between the crystals are occupied by an isotropic base of very slightly brownish tint. In some places it is altered to radial, probably zeolitic matter (? prehnite). Secondary calcite occurs here and there. It may be formed from the isotropic base, which, however, is remarkably fresh and only shows incipient alteration at isolated points.

Occasionally parts of the base let through some light under crossed nicols, the polarization tints being dull blue. It appears to be melilite and shows a tendency to stumpy lath outlines. Some of these laths are isotropic in the middle, with a birefringent zone outside. Part of the isotropic base shows a similar tendency

toward the stumpy lath shapes of melilite, showing also an occasional cleavage crack.

The rock may be designated as a monchiquitic facies of the alnoite, and the question may be brought up as to whether or not the isotropic bases of some monchiquites may correspond in composition with melilite. In some cases (3 and 4) such bases have been shown to have the composition of analcime, but the suggestion just made would appear to be worthy of consideration.

Okaite and Nepheline-Okaite.

These rock types (one of which is described by Howard as nepheline-aplite) occur on the hill immediately north of the farm buildings of Osias Husereau, about two and a half miles south-west of St. Joseph du Lac, Oka Hills, Quebec. The exposure has a length of three-quarters of a mile in a north-easterly direction, and

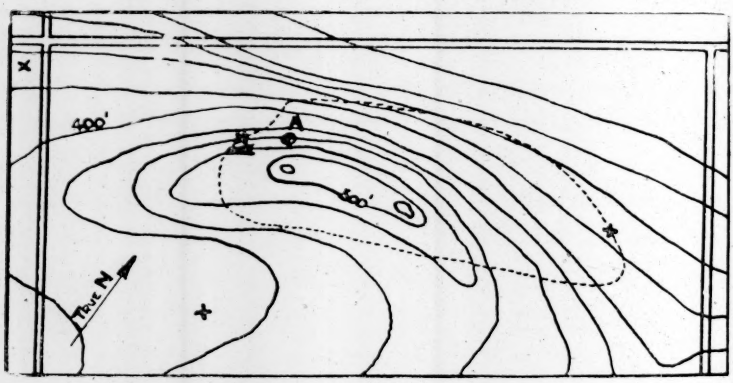


Fig. 2.—Dotted line shows outcrop of okaite; solid black, dike of monticellite-alnoite; *A*, radial apatite occurrence; *X*, altered Grenville Limestone. Road at left of diagram, Ste. Sophie Road; road at top of diagram, Ste. Germaine Road. Scale: 3 inches = 1 mile.

has a width of a quarter of a mile. It forms a plug similar to those of the Monteregian hills, and, as regards superficial area, is of the same order as Mount Johnson. The monticellite-alnoite forms a dike-like mass at the south-western end of the okaite body (see Fig. 2). No proof that the okaite has cut the Palæozoic is to hand, as the rocks of the surrounding district are Pre-Cambrian. From the general characters of the okaites, this occurrence may be regarded as the ninth and most westerly of the Monteregian hills.

Two varieties of the rock are recognized:—*okaite*, composed of melilite, haüyne, and biotite, as essential constituents; and *nepheline-okaite*, composed of the same minerals with nepheline in addition.

In the hand specimen the okaite is fine- to coarse-grained, and of granitic texture. It has a grey colour, showing no felspathic

and practically no ferro-magnesian constituents, with the exception of mica, which occurs here and there as well-formed porphyritic crystals up to one quarter of an inch in diameter. The freshly broken surface of the rock shows a mineral of honey-yellow colour, in places in crystals up to half an inch in diameter, and also a dull bluish-grey mineral of greasy lustre. The former is melilite, being fresh and showing vitreous lustre. The latter includes some melilite lacking the vitreous lustre, because it has undergone a certain amount of alteration. It also includes the haüyne, to which it owes the bluish tint, and in the nepheline-okaite it includes both nepheline and haüyne, the bluish tint being absent. The melilite makes up most of the rock. Calcite may be observed in some parts of the rock, and may be arranged in linear bands or schlieren. The weathered surface of the rock is dull grey and lustreless. Standing up from the weathered surface are the more resistant crystals of mica.

At the northern side of the south-western end of the hill the okaite is coarse-grained and associated with coarsely crystalline calcite, which is very similar to some occurrences of Grenville limestone. Magnetite, in crystals up to one-third of an inch in diameter, well-formed crystals of a dark mica, which reach a diameter of half an inch, and radial aggregates of greenish apatite needles, with diameters up to 3 inches, may be found associated with the coarsely crystalline calcite. This association recalls that of the mica-apatite veins of the Ottawa valley, but magnetite does not occur in those veins, and there is no banded arrangement of the minerals in this occurrence.

In one hand specimen, apparently a contact facies, calcite may be seen as a kind of ground in which the other minerals, melilite, etc., are set or have been developed, the calcite being in crystalline continuity over a space including many silicate individuals. The appearance of this calcite recalls the poikilitic structure. In the same specimen is to be seen garnet, a mineral characteristic of contact metamorphism of calcareous rocks, and also radial aggregates of apatite, a very unusual habit of this mineral.

The Grenville limestone is altered for a few inches from the contact, at the eastern end of the okaite exposure. It is composed of calcite with magnetite, forsterite (positive, 2V near to 90°), and a slightly pleochroic, greenish biotite.

Microscopical Characters.

Under the microscope, the okaite shows the hypidiomorphic structure which is characteristic of plutonic rocks. It is composed of the following minerals, in the order of their importance: melilite, haüyne, biotite, with accessory magnetite, apatite, perovskite, calcite, and pyrites.

The melilite is remarkably fresh, shows good cleavage in many sections, is uniaxial, negative, with refractive indices $\epsilon > 1{\cdot}61$,

$\omega < 1{\cdot}635$, and shows incipient alteration (probably to prehnite) beginning along irregular cracks rather than along cleavages. A partial alteration of the melilite gives rise to a cloudy or dusty appearance, without yielding products capable of identification. The melilite sometimes carries dendritic inclusions of opaque material, probably magnetite, which are very similar in appearance to those often found in olivine. They may have been derived from olivines, which may have crystallized, and then been resorbed with the formation of melilite. (Cf. the opaque inclusions mentioned by Howard (16, p. 80) in what may be melilite identified as nepheline.)

Sometimes the haüyne is cloudy and crowded with many inclusions, in some cases more abundant near the centres of the crystals. Sometimes it is cloudy, apparently by reason of incipient alteration, which has not gone far enough to yield a product which is definitely determinable. Because of the partial decomposition it is not completely isotropic. Its refractive index is less than 1·49. Some sections show cancrinite, in small flakes, formed from the haüyne. Other sections show haüyne of a slightly brownish tint, with alteration to a radial, zeolitic mineral in places. The bluish colour of this mineral in hand specimen is more prominent when it is wet. It contains 10·62 per cent of CaO, 9·03 per cent of SO_3, and several per cent of iron oxide. This latter is to be referred to the very numerous opaque inclusions in the mineral. When the haüyne is treated with dilute HCl, sulphuretted hydrogen is involved, which indicates the presence of the lazurite molecule.

The mica is brown in colour, and strongly pleochroic from light greenish brown to light yellowish. The absorption is rather low for biotite, but the mica may be referred to that species. It is nearly uniaxial, negative, with very small optic axial angle. It often carries inclusions of iron ore.

The magnetite is often enclosed in perovskite. The latter mineral is dark brown in colour, does not show good crystal outline, and is sometimes isotropic. More often it is anisotropic, and often shows lamellar twinning. In large grains this mineral has a black colour, with irregular fracture and adamantine to metallic lustre. It reacts for calcium and titanium, but not for iron or silica. In very thin fragments it shows the violet colour characteristic of Monteregian perovskites, but, in the rock slices, being thicker, the colour is much more brown than violet, and the mineral is so much like melanite in appearance that separation was necessary for its identification. Apatite is fairly abundant. Pyrites is not abundant, and is very variable in amount, from place to place.

The general order of crystallization has been apatite, pyrites, magnetite, mica, perovskite, melilite, nepheline (if present), and haüyne, with slight overlaps as is natural.

Interstitial calcite, in small amount, is present. It may be referred to absorption of Grenville limestone, with which the occurrence is associated.

The nepheline of the nepheline-okaite is quite subordinate in amount to melilite. It is often crowded with transparent inclusions, arranged in certain definite crystallographic directions. It is very fresh, and is uniaxial and negative, with refractive indices ϵ 1·54, $\omega > 1{\cdot}54 < 1{\cdot}55$. The other minerals are as described above.

Separations of the constituent minerals of the okaite have been made, which allow of an approximate estimation of the mode of the rock, as given below, along with that of a variety especially rich in the accessory minerals.

	per cent.		per cent.
Okaite.—Melilite	66 to 63	*Okaite Variety.*	52·5
Haüyne	19 to 20		21
Biotite	8 to 10		8
Magnetite	2		7·5
Apatite	2		2·5
Calcite	2		2
Perovskite	1		6
Pyrites	—		·5

In one of the separations, a yellow, isotropic mineral of high refractive index was noticed. Its colour is between lemon and orange yellow. It has not been seen in the rock slices. It is not completely soluble in the salt of phosphorus bead, and gives an iron reaction. It is probably a garnet, related to grossular.

Chemical Characters.

The okaite has not been analysed as yet. The chemical analysis of the nepheline-okaite is given on page 439 (IV). The outstanding features of its chemical composition are the very high lime and alumina and low magnesia, as compared with alnoites, with which group it is related. The total alkalies are only slightly higher than those of Bowen's melilite-biotite rock from Isle Cadieux, and not very markedly higher than the total alkalies of other alnoites. Some polzenites (5) are richer in alkalies than the nepheline-okaite. The excess of soda over potash is noteworthy in the nepheline-okaite.

Okaite is to be regarded as a plutonic rock with which the dike rock alnoite is genetically connected. As is common in such cases, the plutonic rock and the dike rock, while showing undoubted chemical affinities, have each their marked individualities.

Melilite in a rock is expressed, in the norm, partially, as calcium ortho-silicate. A large percentage of calcium ortho-silicate in the norm may be taken as an indication of the probable presence of melilite in the rock, if it contains a reasonably high percentage of alumina. If melilite is absent from a rock having these indications some explanation of it should be sought. A partial discussion of this question is given below. (Vide p. 446.)

Considering the silicate portion of the norm of the nepheline-okaite (and neglecting iron oxides, which is not completely justifiable), it is seen that it corresponds roughly to 25 per cent nepheline and

75 per cent Ca-Mg-alumino-silicates, but not in the proportions required by the formula of diopside. In Bowen's nepheline-diopside melts (15) nepheline did not crystallize until a 60 per cent nepheline-content was reached; and in melts of 20 per cent and 35 per cent nepheline-content, olivine and pyroxene crystallized, as well as melilite. In the okaites there is some evidence of the early crystallization of olivine, but no evidence of the crystallization of pyroxene, while nepheline (and/or haüyne) has formed in as large a quantity as is possible. So the conclusion is reached that there does not exist a sufficient basis for a close quantitative comparison between the results of Bowen's experiments and the results of the crystallization of the natural rocks, and especially plutonic rocks.

Monticellite-Alnoite.

This rock type occurs at Husereau's farm, near Oka, in association with the okaite described above. It forms a dike-like body, at least a hundred feet wide, at the south-western extremity of the hill. From the inclusion of patches of the okaite within it, it may be regarded as a later intrusion than the okaite. There are also inclusions of re-crystallized limestone in it. It is an extremely variable rock in thin section. In the hand specimen it shows a dark grey colour and porphyritic structure. The porphyritic crystals, which may reach a diameter of more than a quarter of an inch, are mica in abundance, monticellite and augite more rare, and hornblende in a coarser phase near the centre of the dike. The groundmass in which they are embedded is very fine-grained. The rock is very similar in appearance to many alnoites. (It is Howard's camptonite (16, p. 78).)

Microscopical Characters.

Under the microscope the rock shows the porphyritic structure and holo-crystalline groundmass characteristic of hypabyssal types.

The porphyritic elements include the following in the order of their importance, which, however, may vary from place to place in the dike: Monticellite, aggregates of garnet, melilite, and biotite formed from some pre-existing phenocrysts, monticellite of smaller sizes, perovskite, iron ore tending to smaller size, and brownish grey augite. In one slice only was a single phenocryst of chrysolite which has a surrounding rim of monticellite not in optical continuity. A few phenocrysts of a greenish-brown to green hornblende are present near the middle of the dike.

The monticellite has a refractive index and birefringence lower than those of chrysolite and is negative. It rarely shows cleavages. It often has calcite in small patches round its edges, or it may be surrounded by a reaction rim of melilite or isotropic matter which is referred to melilite.

The absorption products of former phenocrysts consist of an

outer rim of brownish garnet, in very small individuals, associated with a colourless mineral. Enclosed within the rim are the same minerals, but garnet in smaller amount, or perhaps absent toward the centre. In some cases flakes of biotite are present toward the middle, but they are not of uniform orientation. The colourless mineral is mostly isotropic, but in places shows the birefringence of melilite. The whole assemblage seems to indicate that these aggregates have been formed from phenocrysts of the monticellite. The rim of melilite sometimes seen around the latter increases this probability. If this interpretation is correct, it would tend to show that melilite and mica of alnoites take the place, in part, of an olivine of an earlier stage of crystallization.

The biotite is not strongly pleochroic for that mineral, and has very small schiller inclusions of opaque iron ore and some larger ones which are not opaque and which are parallel to the cleavage. The biotite crystals sometimes have a reaction border of granular isotropic material of dark greenish-grey colour and high refractive index identified as garnet.

A brownish-grey augite is represented by a few phenocrysts. They may have melilite and biotite flakes inside them, whether as inclusions or derived from the pyroxene it is difficult to determine. Others have a reaction rim of biotite flakes and isotropic material, probably melilite, around them.

The greenish hornblende sometimes present is more nearly like the hornblende of the nepheline-syenite of Montreal than the brown hornblende so characteristic of the camptonite, monchiquite, and alnoite dikes of Montreal. A deeper green edge to this hornblende is evidence of the action of more alkaline fluid in the later stages of consolidation.

The groundmass enclosing the above described phenocrysts and aggregates, and the smaller crystals mentioned below, is clear and colourless. It includes smaller fragments or crystals of the monticellite and apatite, and many long laths of melilite, often with a tendency to parallelism, as well as material without crystal outline, but with the refractive index and the dull blue polarization tints characteristic of melilite. Much of the base is isotropic but has the same refractive index as the melilite, and doubtless should be included under this head. The melilite is a very abundant constituent of the rock.

Through the groundmass there is much iron ore in fine grains, and brownish minerals in roundish, isotropic grains, much of which is undoubtedly garnet, but occasionally the octahedral form can be recognized, which indicates that some of it, at any rate, is perovskite. The very high refractive index serves to distinguish the latter from the garnet.

There is some interstitial calcite in the ground, apparently primary, judging from the fact that it sometimes encloses iron ore and perovskite.

In one section a secondary lemon-yellow garnet was noticed, similar to that noted under okaite.

The rock may be regarded as a member of the alnoite group very rich in melilite, in which chrysolite is generally lacking, but in which monticellite is important. Fine crushing and flotation with bromoform yielded calcite, but no nepheline or felspar, in the lighter portion of this rock.

Chemical Characters.

The chemical analysis of this monticellite-alnoite is given on page 439 (III). It is seen to be very similar to Bowen's melilite-biotite rock from Isle Cadieux, so much so that this may be regarded as proof of Bowen's conception of the derivation of melilite and biotite from monticellite, in part. The reaction relations of these three minerals, in the rock under discussion, show very clearly the derivation of aggregates of biotite and melilite, sometimes accompanied by garnet, from monticellite.

Soda is in excess of potash in Howard's analysis of this rock, but potash in excess of soda in Ennos' analysis. This analysis of Howard's, and Washington's analysis of the melilite-rich monticellite-alnoite of Isle Cadieux are the only analyses of Monteregian alnoites showing soda in excess of potash.

Criticism of N. L. Bowen's Views Regarding the Isle Cadieux Alnoite.

Because of the extremely able manner in which Bowen (15) has interwoven the two subjects, viz. description of the Isle Cadieux alnoite and experimental work on diopside-nepheline mixes, the writer feels that criticism is needed. This simultaneous treatment of the two subjects involves the fallacious deduction that because melilite has been experimentally produced in a certain manner the melilite in certain natural rocks has been formed in a similar way.

In the case of the Isle Cadieux alnoite, Bowen suggests reaction between diopside and nepheline to produce melilite and biotite as end products, and a soda-rich liquid which was removed from the sphere of action to form analcite dikes. But the suggested removal of one of the phases taking part in the reaction cannot be justified in all cases.

Since, in the cases at Husereau's farm, discussed in this paper, the analyses show high lime and low soda contents, along with the abundance of monticellite in the dike rock, as well as very clear reaction relations between the monticellite and a biotite-melilite aggregate (sometimes with garnet in attendance), the writer believes that the action of $CaCO_3$ in the form of limestone may be held to have given rise to the interesting occurrences under discussion. The more does this appear to be the case because of the close relations of the igneous rocks with the limestone

in the field, at Husereau's farm, where the silicates may be seen developed in the limestone, suggesting the action of a liquid moving by means of progressive solution of the limestone, taking its place and giving rise to new silicates, of which melilite is the most important in amount. The relations of the igneous rock with the limestone, near the contact, indeed, recall very clearly the process known as "replacement", which is to be regarded as accompanying the main act of intrusion.

If these views are held to be correct, the difficulty involved in the removal of an important reacting agent (such as the nepheline-rich liquid of Bowen) disappears, and the explanation of the occurrence retains a more rational appearance, because it requires only the play of such reagents as are demonstrably present on the ground. (It is noteworthy that the total volume of the analcite dikes of the Monteregian petrographical province is insignificant, and also that, up to the present time, none have been recorded in the particular districts which are discussed in this paper.)

The writer regards the field details of the occurrence of the okaite neck, coupled with the analyses of the two associated rocks (nepheline-okaite and monticellite-alnoite), as giving very strong support, one might almost say proof, of the action of limestone, in the production of what are known as the alkaline rock types, a conception which has been so ably advocated by Daly (10).

Bowen admits (15, p. 14) "the formation of such minerals as monticellite and melilite might at first thought be considered to require a lime-rich liquid", and also (p. 5) suggests that calcite is formed in one of the stages of the consolidation of the rock, alnoite.

Bowen writes (15, p. 28): "The presence in a rock of the lime-rich mineral melilite need not therefore be considered as indicating the existence of a magma particularly rich in lime, but rather of an alkali-rich magma from which melilite-bearing facies might be formed by differentiation (crystal accumulation)." The analyses given on p. 439 appear to indicate magmas "particularly rich in lime" rather than "alkali-rich" magmas, and the progressive character of the richness in lime is especially noticeable, as well as the absence of a marked progressive increase of alkalies.

Though Bowen may have "proved experimentally that nepheline reacts with diopside to form melilite" (15, p. 33), it does not follow that the melilite of natural rocks have been formed in this way. Indeed, the writer's view is that the melilites in alnoites, for the most part, have not been formed in this way.

In the writer's view, solution of a shaley limestone in a magma is capable of giving rise to a parent magma of the composition of okaite (cf. Anal. IV, p. 439), from which the alnoites described herein and the peridotite of La Trappe could be derived by crystal accumulation, and intrusion of early products of consolidation of the parent magma, accompanied by greater or smaller amounts

of this parent magma. (No views on the manner in which crystal accumulation may take place will be expressed here.)

After the desilication of a magma, and its enrichment in lime and alumina by solution of impure limestone a composition may be reached of such a nature that the magma, if solidified slowly at depth, would yield melilite and biotite, or melilite, biotite, and nepheline or haüyne as end products. Such a liquid need be no richer in alkalies than the 5·6 per cent shown in the Analysis IV, p. 439. The alkalies may join in the constitution of the biotite and melilite, or help to form nepheline and haüyne, and are not regarded as having been accompanied by an excess of alkalies which has been removed.

Such a biotite-melilite-nepheline mix would doubtless give rise to chrysolite and augite in the earlier stages of consolidation. A local concentration or accumulation of such crystals alone may give rise to a rock like the peridotite of La Trappe, or along with some of the mother liquor might conceivably be intruded in dike form and consolidate as alnoite if cooled quickly, or as monchiquite if cooled still more rapidly. If cooled a little more slowly the reactions described for the Isle Cadieux (15) and Husereau's farm alnoites have a chance to proceed with the formation of monticellite, and the replacement of chrysolite, monticellite, and augite by the biotite and melilite, which are among the end products of the magma.

The writer considers it more in accordance with the facts to regard the whole sequence of events as portraying the vicissitudes of a biotite-melilite-nepheline mix than to regard melilite as the product of a reaction between diopside and nepheline.

Since these views present themselves so forcibly to some of those who have studied the richly melilitic rocks in detail (see also Scheumann (5)), it appears that they should receive adequate consideration before a decision regarding the genesis of these rocks is reached. One might go so far as to say that these views should be disproved before other views, which do not wholly meet the requirements of the field occurrences, may be regarded as acceptable.

The foregoing makes it clear that it is not necessary to assume, with Bowen (17), that the melilitic rocks, if cooled slowly, would give a chance for melilite to be destroyed by a reaction yielding, as end products, nepheline and pyroxene. Rather does it appear that biotite and melilite are practically always among the end products of solidification of the alnoitic magmas, and that chemical composition of a magma may be a more important factor than speed of cooling in determining the presence or absence of melilite in the rock.

The important features of the chemical compositions of melilite-bearing volcanic and dike rocks, which are to be regarded as controlling the presence or absence of melilite are :—

1. Low silica percentage . . . (43·36–27·52 per cent.)
2. High CaO percentage . . . (9·29–28·06 per cent.)

3. Moderate to high Al_2O_3 percentage (5·90–19·05 per cent.) (MgO percentage is not of great importance, and may vary widely (3·97 per cent to 26·41 per cent), as may also iron oxide percentages, without essentially affecting the fate of melilite.)

These figures are to be regarded as approximations to the limiting conditions of composition of natural magmas from which melilite may crystallize, and are subject to correction with advance of experimental knowledge. Melilite may crystallize from a melt from which alkalies are absent, and in natural rocks only low percentages of alkalies, e.g. 2·05 per cent, are sufficient to ensure the crystallization of melilite, under certain temperature and pressure conditions. (Isle Cadieux melilite-rich monticellite-alnoite.) Yamaskite, faisinite and ijolite fall within the limits set forth above, except for alkalies 1·93 per cent in the first, and yet have crystallized without the formation of melilite. The damkjernite dikes of the Fen district also fall within these limits, but have no melilite.

In the Polzen rocks (5) melilite crystallizes before pyroxene, sometimes to its exclusion. The rocks show high soda content, relatively to potash. In the Alnö and most of the Monteregian alnoites potash is slightly more abundant than soda; melilite is still present, but pyroxene plays a more prominent rôle, and crystallizes before melilite. In damkjernite, where potash is markedly superior in amount to soda, melilite is completely shut out. It appears to be justifiable to suggest that soda plays an important part in extending the conditions under which melilite may form, while potash tends to restrict these conditions. Bowen's experiments have shown the importance of soda in extending the conditions under which melilite may form.

Rôle of CO_2.

With effusive and dike rocks, CO_2 formed by dissociation of absorbed limestone has a chance to escape as a result of lower pressure near the surface. Thus CaO may be set free to act with its full force in those reactions which produce monticellite and melilite. It is possible that where the escape of CO_2 is prevented, its chemical affinity for CaO may prevent the complete effect of the latter in the reactions mentioned, and pyroxene (or hornblende) may be formed rather than melilite. In this connexion the high CO_2 content of damkjernite (up to 10·24 per cent) may be mentioned.

This rôle of CO_2 may also have something to do with the absence of melilite from some plutonic rocks, whose chemical compositions fall near the limits given above, for the occurrence of melilite in effusive and dike rocks, and which at the same time have soda in excess of potash, e.g. yamaskite, faisinite, and ijolite. A comparison of the analyses of these rocks with that of nepheline-okaite, seems to indicate, however, that very high lime content is essential to the formation of melilite in plutonic rocks.

[*Note.*—The analyses brought together by Scheumann (5) serve to illustrate the above discussion.]

General Considerations.

The consanguinity of the rocks of the Monteregian petrographical province has been pointed out (6), and the date of the igneous activity to which these rocks are due is defined by limits set by the presence of Oriskany-Onondaga (lower middle Devonian) limestone in the igneous breccia of St. Helen's Island (7) on the one hand, and by the fact that Shefford and Brome Mountains were subjected to pressure associated with the formation of the Appalachian mountains (Carboniferous to Permian) on the other hand.

From the published descriptions of the rocks of this petrographical province, it may be seen that, in passing away from the south-eastern limit of the petrographical province toward the west and north-west, types characterized successively more and more strongly by the presence of the felspathoid minerals or melilite are met. This generalization is not absolutely applicable because the rocks of Johnson and St. Hilaire are more strongly characterized by felspathoids than those of some of the localities farther west. The generalization receives very considerable support, however, from the descriptions of the alnoites and the okaites given above. The rocks herein described are more strongly characterized by felspathoids and melilite than the rocks previously known in this petrographical province, and they are found along its extreme western and north-western borders.

With regard to the mode of origin of a hypothetical uniform parent magma for the petrographical province, and the possible differentiation of this into different submagmas, little need be said here, since these considerations belong to the field of speculative geology. Attention may be called, however, to the general correspondence of the changes in the petrographical province in moving away from the Appalachian mountain system with those which would be required in accordance with an elaboration of Harker's attempt to connect petrographical provinces of strongly alkaline rocks with the undisturbed foreland regions connected with orogenic earth-movements of major type (9). It is possible that we have to deal, in this petrographical province, with a result of partial "separation brought about between the fluid and the crystalline part (of a parent magma), the former . . . relatively rich in alkali and particularly in soda" . . . "the liquid part tending to be driven from places of great to places of less stress." "When in such a region an unequal distribution of crustal stresses is maintained sufficiently long, there will be a continued flux of the interstitial magma, which will be driven out from areas of special disturbance to accumulate beneath areas of relative quiescence."

It may be suggested that collection of the liquid portions of magma, as outlined, might result in a distinctly superheated magma

capable of dissolving considerable amounts of limestones or dolomites.

Daly's thesis (10) concerning the establishment of alkaline magmas by the absorption of limestones by more normal magmas is of considerable interest. In this connexion he drew up a list of the known occurrences of alkaline rocks, tabulating, at the same time, the limestones which they cut. It might be said that subalkaline rocks which cut limestones are also known. If proof can be obtained that limestone has had some effect upon the molten magma, such a list of occurrences would be very important. Probably the case which gives most ample proof of such effect of limestone upon a magma is that of the Haliburton-Bancroft district of Ontario (11). It may be pointed out, however, that Barlow was not prepared to go as far as Daly regarding this possible effect (12).

The rocks of the Monteregian petrographical province are listed by Daly as cutting Ordovician and Pre-Cambrian limestones and dolomites. There is little evidence that there has been any extensive assimilation of Ordovician limestones by the magmas. It seems probable, however, that absorption of Grenville limestone from the Pre-Cambrian terrane beneath may have had an important effect in setting up an "alkaline" magma. This conception receives support from the association of the okaites of Husereau's farm, Oka, with altered Grenville limestone, and the development of melilite, etc., within calcite by replacement (see p. 441), even though the scale is small as compared with the Haliburton-Bancroft occurrences. The presence of primary calcite in the very fresh alnoites also has an important bearing on the same question. From the studies herein described, the writer would conclude that Daly's thesis concerning the origin of alkaline magmas by the assimilation of limestone receives strong support, but in this particular petrographical province the writer would have recourse to the Pre-Cambrian rather than to the Ordovician limestones.

Smyth (13) and Bowen (14) prefer to credit the "mineralizers" with the chief rôle in the differentiation of alkaline rocks from subalkaline magmas, though Bowen is ready to allow the possibility of the effect of limestone in some cases. Daly lays stress upon the rôle of carbon dioxide, and the occurrences herein described point in the same direction. It appears probable that each of the several conceptions mentioned above will need to be applied in the explanation of the production of certain individual alkaline magmas, and in some cases more than one, or even all of them. The attitude of the present must be that of the open mind, awaiting new experimental data.

Bowen's very interesting experimental studies connected with the Isle Cadieux alnoite (15) deal rather with the hypothetical vicissitudes of alkaline magmas after their production than with the formation of alkaline magmas from subalkaline magmas.

Scheumann has described a district (Polzen region (18)) of

Tertiary volcanic necks and associated dike rocks, for which the general mode of occurrence, as well as the chemical compositions of the rocks themselves, are very similar to those of the Monteregian petrographical province. The volcanic necks or pipes are filled with tuffs and fragments of dikes and lavas and country rock. There are no sheets of lava nor important bodies of ashes surrounding the pipes, which have simply been explosion centres from which the country rocks have been blown out along with small amounts of the igneous rock. These have fallen back together into the mouths from which they were blown repeatedly, forming breccias. It is reasonable to suppose, from Scheumann's descriptions (5 and 18), that an important motive force of these explosions was the pressure set up by CO_2 formed by dissociation of the limestone absorbed by the magma at depth.

The parallel with the Monteregian pipes or necks is almost complete, with the exception that instead of superficial manifestations of vulcanicity, the Canadian necks present features connected with greater depths. There may have been removed by erosion from the Montreal district from 2,000 to 3,000 feet of strata belonging to the upper Ordovician, Silurian, and Devonian systems, since the period of the igneous activity. But the probability that the necks led to openings at the surface is strong, when the character of the inclusions of the St. Helen's Island breccia is taken into account (7). Fragments of country rocks from higher horizons than those surrounding the pipes are known also in the Polzen district. The characters of the breccias of the Montreal district point to the explosive character of the vulcanicity, and the composition and field relations of at least one of the pipes (that at Husereau's farm) point to carbon dioxide pressure as probably an important motive force connected with the explosions.

In both districts the majority of the igneous necks break through the almost flat-lying strata forming part of the foreland to a folded mountain chain lying to the south-east, of which the formation was roughly contemporaneous with the igneous activity. The Monteregian pipes break through the Palæozoic.

The Polzen pipes break through the Cretaceous strata, which have been dropped down by faulting into the Bohemian massif of Pre-Cambrian and Palæozoic rocks.

Conclusions.

The limits, toward the west and north-west, of the Monteregian petrographical province have been extended by the discovery of rocks which are clearly referable to this petrographical province, as a result of the work of the Road Materials Division of the Department of Mines of Canada. The discoveries include a plug of okaite, which forms the ninth and most westerly of the Monteregian hills, a monticellite-alnoite, associated with the okaite as a dike, and a number of alnoites.

The remarkable freshness of these rocks is a point which should be emphasized. The alnoites are the freshest on record, and offer the first opportunity of getting a chemical analysis of an unaltered alnoite. As a result, this district will probably become more important than the original locality of Alnö I. from the point of view of field development of the interesting rock type, alnoite. The development of a facies of alnoite which approaches very closely to the monchiquites bears upon the question of the relations of this latter group, which may, in reality, be a composite group. The monchiquites of the Monteregian petrographical province are certainly very close to the alnoites. In other localities the importance of an analcime base in monchiquites may indicate other affinities.

Okaite is a plutonic relative of the alnoite group, but is free from olivine and very rich in melilite. Melilite, haüyne, and biotite are its essential constituents. Nepheline-okaite is a type carrying nepheline in addition to the minerals mentioned.

From their geographical distribution and very close chemical affinities, the alnoites of Como, Isle Cadieux, Cascades Point, Ste. Anne de Bellevue, Isle Bizard, Ste. Monique, and Husereau's farm, together with the related types of La Trappe and, perhaps, also the breccias of Ste. Dorothée, are to be regarded as genetically connected with the okaite plug of Husereau's farm.

Harker's conception with regard to the relation between alkaline magmas and the undisturbed forelands of folded mountain chains appears to be supported by the general distribution of the various rock types in the Monteregian petrographical province. The details of the latest-found plug, that of Husereau's farm, appear to lend support to Daly's view of the formation of alkaline magmas by absorption of limestones.

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The Subgenera of *Lichas*.

By F. R. Cowper Reed, Sc.D., F.G.S.

IN 1902[1] the author proposed a new classification of the genus *Lichas*, introducing several new subgeneric names. Gürich's[2] valuable paper dealing with the same subject, which was published late in 1901, unfortunately only came into his hands after his article was in the press, so that full justice could not be done to it. Since that time a considerable amount of work has been done on the genus *Lichas*, but the principles governing the classification put forward in 1902 have not been upset, and no fundamental modifications have been introduced, though many new species have been described and several new subgeneric or generic divisions have been established.

One of the most important recent contributions dealing with the relations of the various members of the family is that by Foerste.[3] In this he points out the parallelism of structure in certain of the genera (or subgenera), and insists that it is necessary to take into account the characters of both the cranidium and pygidium before we can safely determine the generic (or subgeneric) reference of species. In so far as Gürich failed to do this, his scheme of classification is open to objection. But the difficulties in the correct subgeneric assignment of many of the European species is often due to our knowledge of them being confined to isolated head-shields or pygidia, or to the tentative association of these parts being often based on weak evidence and therefore open to doubt.

In the light of the various investigations made since 1902 the following divisions of the two main groups of the genus which were then established can be recognized, but they fit into the original classification, and require only slight changes in the definitions of some of the subgenera as a result of some of Gürich's names and those of other palæontologists being now adopted or added. A few species which were of doubtful reference to any of the author's "sections" (= subgenera) in 1902 may now be considered as belonging to distinct subgeneric types.

In some cases the names which Gürich proposed in place of those instituted by Corda or others are not here adopted, because there does not seem to be any adequate reason for discarding the old terms, although Richter[4] has done so.

Weller, in 1907,[5] followed the author's classification in the main, and gave a full definition of the subgenera *Corydocephalus*, *Dicranopeltis*, *Metopolichas*, and *Arctinurus*, but his *Metopolichas*

[1] Reed, *Quart. Journ. Geol. Soc.*, vol. lviii, 1902, pp. 59–82.

[2] Gürich, *Neues Jahrb. f. Miner. Geol.*, Beil. Bd. xiv, 1901, pp. 519–39, t. xviii, figs. 1–8, and t. xx.

[3] Foerste, *Amer. Journ. Sc.*, vol. xlix, 1920, pp. 26–50, pls. i–iv.

[4] Richter, *Neues Jahrb. f. Miner. Geol. Jahrg.* 1917, i, pp. 50–72, t. v, vi.

[5] Weller, Bull. No. iv, pt. ii, *Nat. Hist. Surv. Chicago Acad. Sc.*, 1907, pp. 233–50.

includes *Autolichas*, which is a new name (see below) applied to the group of *L. affinis* which Foerste (op. cit.) has recognized as distinct.

In the following list the new subgeneric names which did not find a place in the author's classification of 1902 are marked with an asterisk (*), and those of which the definition has been modified in consequence of the removal of certain forms are marked with a dagger (†).

GROUP I.

I. †*Corydocephalus* Corda, 1847 (= *Plusiarges* Gürich, 1901). Type: *L. palmata* Barrande.
II. **Hemiarges* Gürich, 1901. Type: *L. wesenbergensis* Schmidt.
III. **Euarges* Gürich, 1901 (= *Acanthopyge* Corda, 1847; now Gray, 1838). Type: *L. haueri* Barrande.
IV. **Dicranogmus* Corda, 1847 (= *Liparges* Gürich, 1901). Type: *L. simplex* Barrande.
V. **Craspedarges* Gürich, 1901. Type: *L. Wilcanniae* Gürich.
VI. **Eiffiarges* Richter, 1917 (*Neues Jahrb. f. Miner. Geol.*, 1917, i, p. 55, t. v, figs. 1, 2). Type: *L. caudimirus* Richter.
VII. *Dicranopeltis* Corda, 1847 (= *Trachylichas* Gürich, 1901).
VIII. *Platylichas* Gürich, 1901. Type: *L. margaritifer* Nieszkowski.
IX. †*Metopolichas* Gürich, 1901 (= *Metopias* Eichwald, 1842, non Gory, 1832). Type: *L. hubneri* Eichwald.
X. *Metalichas* Reed, 1902. Type: *L. cicatricosus* Schmidt (non Loven).
XI. *Uralichas* Delgado, 1892. Type: *L. ribeiroi* Delgado.
XII. *Ceratarges* Gürich, 1901. Type: *L. armatus* Goldfuss.
XIII. *Oncholichas* Schmidt, 1885. Type: *L. ornatus* Angelin.
XIV. **Platopolichas* Gürich, 1901. Type: *L. avus* Barrande.
XV. **Arctinurus* Castelnau, 1843 [1] (= *Pterolichas* Gürich, 1901). Type: *L. boltoni* Bigsby.
XVI. **Autolichas* Reed, nom. nov. 1923. Type: *L. affinis* Angelin.
XVII. *Gaspelichas* Clarke, 1907. Type: *L. forillonia* Clarke (*Bull.* 107, New York State Mus., 1907, pp. 167–70, text-figs.).
XVIII. **Radiolichas* Reed, nom. nov. 1923. Type: *L. aranea* Holzapfel.

GROUP II.

XIX. *Hoplolichas* Dames, 1877. Type: *L. tricuspidatus* Beyrich.
XX. *Homolichas* Schmidt, 1885. Type: *L. depressus* Angelin.
XXI. *Conolichas* Dames, 1877. Type: *L. æquiloba* Steinhardt.
XXII. *Echinolichas* Gürich, 1901. Type: *L. eriopis* Hall.
XXIII. *Leiolichas* Schmidt, 1885. Type: *L. illænoides* Nieszkowski.
XXIV. †*Amphilichas* Raymond, 1905 (*Amer. Journ. Sc.*, xix, 1905, p. 378 = *Paralichas* Reed, 1902). Type: *L. lævis* Eichwald.
XXV. *Terataspis* Hall, 1863. Type: *L. grandis* Hall.
XXVI. *Ceratolichas* Hall, 1888. Type: *L. gryps* Hall.
XXVII. **Acrolichas* Foerste, 1919 (*Ohio Journ. Sc.* xix, 7, 1919, p. 402, and op. cit. 1920). Type: *L. cucullus* Meek and Worthen.

The definitions of the newly accepted subgenera, and the modifications of the definitions of others which are now necessary, are given below. But for the remaining subgenera the author's definitions laid down in 1902 still hold good and therefore need not be repeated.

I. *Corydocephalus*.—Cranidium with axial furrows complete, and the bicomposite, fourth lateral, occipital and central lobes of the

[1] This subgenus is redefined by Weller, op. cit., p. 247.

glabella well developed and completely separated and circumscribed by furrows. Pygidium composed of three pairs of pleuræ, with corresponding free points on the margin; first two pairs of pleuræ complete and with pleural furrows; third pair without pleural furrows, and only separated in median line by narrow postaxial piece; axis well defined, short, cylindrical; border of pygidium usually forming raised marginal band.

Type: *L. palmata* Barrande.[1]

Remarks.—The complete bicomposite, fourth lateral and occipital lobes, the complete axial furrows, and the well-circumscribed central lobe of the glabella distinguish this subgenus from *Hemiarges*, *Euarges*, *Dicranogmus*, *Craspedarges*, and *Eifliarges*. The pygidium is distinctive, though more like *Euarges* than like the others. Foerste[2] maintains that Beyrich's earlier name *Trochurus* should be used in place of *Corydocephalus*.

II. *Hemiarges*.—Cranidium with bicomposite lobes well circumscribed or incomplete posteriorly; fourth lateral lobes indistinctly marked off from cheeks; axial furrows weak posteriorly. Occipital lobes indistinctly differentiated, ill-defined in front. Pygidium composed of three pairs of pleuræ, of which the two first are complete and bear pleural furrows and project freely beyond margin; third pair broad, without pleural furrows, but having two short points on margin, and separated by long axis and short narrow postaxial piece. Axis long, cylindrical, of many annulations, well defined.

Type: *L. wesenbergensis* Schmidt.[3]

Remarks.—*Hemiarges* differs from *Corydocephalus* in the fourth and occipital lobes being small and indistinctly defined, in the obsolescence posteriorly of the axial furrows, in the absence of a raised border to the pygidium and in the bidentate termination of the third pleuræ.

III. *Euarges*.—Cranidium with bicomposite lobes circumscribed and marked off from central lobe. Fourth lateral lobes large, fused with cheeks; axial furrows incomplete and obsolete behind bicomposite lobes. Occipital lobes absent. Pygidium composed of three pairs of pleuræ, all ending in free points on margin, with first two pairs complete with pleural furrows; third pair without pleural furrows and separated by very narrow median postaxial piece; axis short, cylindrical, well defined; border without raised marginal band.

Type: *L. haueri* Barrande.[4]

Remarks.—*Euarges* differs from *Hemiarges* by the absence of occipital lobes and the complete fusion of the large fourth lateral lobes with the cheeks. From *Corydocephalus* it differs in these

[1] Barrande, *Syst. Silur. Bohême*, vol. i, p. 599, pl. xxix, figs. 1–13.

[2] Foerste, *Ohio Journ. Sc.*, vol. xvii, No. 7, 1917, p. 254.

[3] Schmidt, *Rev. Ostbalt. Trilob. Abt. II* (*Mem. Acad. Imper. Sc. St. Petersb.*, xxxiii, No. 1, 1885), p. 44, t. vi, figs. 1, 2 (? 3–6).

[4] Barrande, op. cit., p. 664, pl. xxviii, figs. 30–44; Gürich, op. cit., t. xx, fig. 9.

respects and by the absence of axial furrows behind the bicomposite lobes, while the pygidium differs in having no raised border.

IV. *Dicranogmus.*—Cranidium with first lateral furrows obsolete, the bicomposite lobes being undefined anteriorly and fused with first lateral lobes and central lobe of glabella; fourth lateral lobes fused with cheeks; central lobe parallel-sided, well defined behind; occipital lobes present. Axial furrows incomplete posteriorly. Pygidium undescribed.

Type: *L. simplex* Barrande.[1]

Remarks.—The undefined anterior ends of the bicomposite lobes and the fusion of the fourth lateral lobes with the cheeks distinguish *Dicranogmus* from *Corydocephalus*, and the latter feature allies it with *Euarges*.

V. *Craspedarges.*—Cranidium with bicomposite lobes completely circumscribed; fourth lateral lobes fused with cheeks; axial furrows incomplete posteriorly, occipital lobes absent; central lobe well defined and circumscribed. Pygidium (incompletely known) composed of seven (?) pairs of pleuræ ending in freely projecting marginal spines on each side.

Type: *L. Wilcanniæ* Gürich.[2]

Remarks.—The head-shield seems much like *Euarges*, but the many pleuræ of the pygidium with their free points suggest relations with *Eifliarges*.

VI. *Eifliarges.*—Cranidium with bicomposite lobes completely circumscribed; fourth lateral lobes indistinctly marked off from cheeks, the axial furrows posteriorly being weak or obsolete; central lobe well defined and circumscribed; occipital lobes absent. Pygidium with well-defined short, cylindrical axis; lateral lobes composed of six pairs of distinct complete pleuræ, ending in free spinose points and of two posterior fused pairs of pleuræ likewise ending in free spinose points.

Type: *L. caudimirus* Richter.[3]

Remarks.—As regards its head-shield, *Eifliarges* is allied to *Euarges*, and Richter himself comments on the resemblance of its pygidium to that of *Craspedarges*.

IX. *Metopolichas.*—Cranidium with bicomposite lobes incompletely defined behind; fourth lateral lobes large; occipital lobes present; axial furrows complete. Pygidium with three pairs of pleuræ, all with pleural furrows and ending in free points on margin; the third pair incompletely marked off from broad postaxial piece; axis short, undefined behind.

Type: *L. hübneri* Eichwald.[4]

[1] Ibid., p. 608, pl. xxviii, figs. 14, 15; Gürich, op. cit., t. xx, fig. 7.

[2] Gürich, op. cit., p. 532, t. xviii, figs. 1, 1*a*, 6–8, t. xx, fig. 20. W. N. Benson alters the spelling of the name to *Craspidarges* (*Rec. Geol. Surv. N.S. Wales*, vol. x, pt. ii, 1922, p. 115).

[3] Richter, *Neues Jahrb. f. Miner. Geol.* 1917, i, p. 55, t. v, figs. 1, 2, text-figs. 1*a–c*, pp. 58, 59.

[4] Schmidt, *Rev. Ostbalt. Trilob. Abt. II* (*Mem. Acad. Imper. Sc. St. Petersb.*, xxxiii, i, 1885), p. 65, t. i, figs. 13, 14.

Remarks.—The glabellar characters are much like those of *Platopolichas*, and indeed no constant differences have so far been recognized, but the pygidium differs by the presence of pleural furrows on the third pleuræ and by the postaxial piece widening posteriorly instead of narrowing.

XIV. *Platopolichas.*—Cranidium with large, bicomposite lobes more or less circumscribed behind; fourth lateral lobes rather small; occipital lobes present; axial furrows complete. Pygidium of three pairs of pleuræ, all possessing free points; first two pairs with pleural furrows, but third pair without pleural furrows. Postaxial piece narrowing posteriorly, more or less completely bounded at sides. Axis short, undefined behind.

Type: *L. avus* Barrande.[1]

Remarks.—The points of difference between this subgenus and *Metopolichas* have been mentioned above, and seem to lie only in the pygidium.

XV. *Arctinurus.*—Cranidium with bicomposite lobes extending back to occipital furrow; fourth lateral lobes squeezed out and quite obsolete. Occipital lobes absent; axial furrows complete. Pygidium composed of three pairs of pleuræ, all with pleural furrows and ending in free points on margin; third pleuræ complete or nearly complete, separated by broad postaxial piece; axis short, undefined behind.

Type: *L. boltoni* Bigsby.[2]

Remarks.—The squeezing out of the fourth lateral lobes so that the bicomposite lobes reach back to the occipital furrow is a further stage of that found in *Metalichas*. The absence of occipital lobes distinguishes it from *Metopolichas* and *Platopolichas*. The pygidium is practically identical with that of *Metopolichas*.

XVI. *Autolichas.*—Cranidium with bicomposite lobes very long, often incomplete behind; fourth lateral lobes very small, nearly squeezed out; axial furrows complete, or weak posteriorly; occipital lobes well defined. Pygidium semilanceolate, simply pointed or rounded behind; the first two pleuræ ending in free points projecting beyond margin, the third pair without free points, not projecting at all and incomplete, separated by postaxial piece; all pleuræ with pleural furrows.

Type: *L. affinis* Angelin. (Palæont. Scand., p. 69, pl. 36, fig. 2*a*; pl. 38, fig. 4*b*.)

Remarks.—The glabellar characters recall *Platopolichas* very closely, but the unbroken, rounded, or simply acuminate posterior margin of the pygidium behind the second pair of pleuræ distinguish it, the third pleuræ not showing on the margin. The absence of pleural furrows on the third pleuræ is like *Platopolichas*, but the

[1] Barrande, op. cit., Suppl., p. 40, pl. v, fig. 23; pl. vi, figs. 22–6; pl. x, figs. 12–19; Foerste, op. cit. 1920, pl. iii, figs. 7*a*, *b*.

[2] Bigsby, *Journ. Acad. Nat. Sc. Philad.*, Ser. I, 4, pt. 2, 1825, p. 365, pl. 23.

postaxial piece widens posteriorly as in *Metopolichas*. A well-known example of this new subgenus is *L. laciniatus* Wahl. (Angelin, Palæont. Scand., p. 73, pl. 36, fig. 1.)

XVII. *Gaspelichas*.—Frontal lobe large, ovoid, prominent, most elevated posteriorly, bearing three pairs of large recurved spines. Lateral lobes long, narrow, low, subcrescentic, rising posteriorly into elevated posterior areas (? = fourth lateral lobes) and bearing two unequal pairs of spines. Axial furrows weak. Occipital ring broad, flat, armed with two pairs of marginal spines and one median spine.

Type: *L. forillonia* Clarke.[1]

Remarks.—The true relations of this aberrant form are doubtful, but it seems to have affinities with *Ceratarges*.

XVIII. *Radiolichas*.—Glabella composed of median lobe and pair of elongated oval bicomposite lobes; fourth lateral lobes and occipital lobes absent. Pygidium with broad unsegmented axis; pleural lobes much reduced, very narrow, furnished with three pairs of lateral spines representing the pleuræ, and one median terminal spine.

Type: *L. aranea* Holzapfel.[2]

Remarks.—The type comes from the upper part of the Middle Devonian of the Rhenish area. The structure of the glabella appears to be like that of *Oncholichas*, but the pygidium is unique in character, the pleuræ being represented only by spines. *L. contusus* Hall (Palæont. New York, vol. v, p. 33, pl. xixB, figs. 3–6) and *L. Maureri* Novak (Palæont. Abh. N.F. Bd. 1, Heft 3, 1890, p. 30, t. iii, figs. 9, 9*a*) are allied species.

XXIV. *Amphilichas*.—Cranidium with tricomposite complete lobes. Occipital lobes absent. Axial furrows complete, or incomplete behind. Pygidium composed of three pairs of pleuræ, each with pleural furrow, the first and second pairs complete and projecting freely beyond margin; the third pair incomplete, but with two short, unequal marginal points, the posterior ones very close together; postaxial piece wide, not marked off posteriorly from pleuræ. Axis short, undefined behind.

Type: *L. laevis* Eichwald.[3]

Remarks.—The characters of the glabella are such as were described by the author for his section *Paralichas* (name preoccupied) (Section F, Group II, op. cit. 1902, p. 80), and Foerste has remarked that the cranidium is practically identical in structure with that of *Acrolichas*, but the pygidium is quite dissimilar. The bidentate marginal projections of the third pleuræ recall *Hemiarges*, but otherwise the pygidium is more like that of *Metopolichas*, and the third pleuræ likewise have pleural furrows.

[1] Clarke, Mem. 9, New York State Mus., 1908, p. 137, pls. 1, 2, 3.

[2] Holzapfel, Abh. Kon. preuss. geol. Landesanst. N.F., xvi, 1895, p. 32, t. iii, fig. 11; t. xiii, figs. 1–4, 16.

[3] Schmidt, op. cit., p. 49, t. vi, figs. 5–10.

XXVII. *Acrolichas*.—Cranidium with complete tricomposite lobes. Occipital lobes absent. Axial furrows complete. Pygidium with three pairs of pleuræ, all with free tips, but only first two with pleural furrows; postaxial piece narrowing posteriorly to an acute point reaching notch between third pair of pleuræ.

Type: *L. cucullus* Meek & Worthen.[1]

Remarks.—The name *L. kildarensis*, which was proposed in 1902 for the *Amphilichas*-like head-shield of *L. hibernicus* Portl. must be definitely dropped, as the author suspected in 1914.[2] The association of the pygidium of *L. hibernicus* Portl. with *Metalichas*, on the strength of its resemblance to *L. cicatricosus* Schmidt is proved to be an error and only a case of parallelism of structure, for its reference to *Acrolichas* is clearly established by Foerste's work. The practically identical structure of the head-shields of *Amphilichas* and *Acrolichas* is mentioned by Foerste (op. cit., p. 32) as an example of parallelism of structures in different genera, but the pygidia of these two groups are quite dissimilar. Foerste considers that the association of the glabella and pygidium of the genotype of *Amphilichas* needs verification. The same author points out the parallelism of structure in the pygidia of *Acrolichas* and *Metalichas*.

For figures of the above-defined subgeneric groups the works to which reference has been made should be consulted.

The peculiar pygidium described by Angelin,[3] and more recently by Olin,[4] as *Lichas quadrispinus* would certainly require a new subgenus for its reception if it could be regarded as truly belonging to this genus. But its very close resemblance to the pygidium of some species of *Remopleurides*, and especially to *R. nicholsoni* Reed,[5] from the Drummuck group of Girvan, is so close that personally I do not feel any doubt that it is referable to the latter genus.

It may be mentioned that Messrs. Etheridge and Mitchell[6] have recently used the subgeneric name *Acanthopyge* Corda for an Australian species, *L. australis* McCoy, of Silurian age, apparently in ignorance that it was pre-occupied and that Gürich had proposed the name *Euarges* for it.

The British species or varieties of *Lichas* which have been established since 1902 include Ordovician and Silurian forms.

In 1903 the author described two new varieties of *Corydocephalus*

[1] Meek and Worthen, *Geol. Surv. Illinois*, iii, 1868, p. 299, pl. i, figs. 6*a–c* (head only); Foerste, op. cit. 1920, pp. 29, 32, 33, 42, pl. i, figs. 1*a–g*, and references.

[2] Reed, "Lower Palæozoic Trilobites of Girvan": *Palæont. Soc. Suppl.* 1914, p. 30.

[3] Angelin, *Palæont. Scand.*, 1854, p. 84, t. xl, fig. 20.

[4] Olin, *Chasmopskalk. o. Trimicleusskiff. Skåne* (*Medd. Lunds Geol. Fältkl.*, Ser. B, No. 1, 1906), p. 54, t. i, fig. 29.

[5] Reed, "Lower Palæoz. Trilob. Girvan": *Palæont. Soc. Suppl.* 1914, p. 12, pl. ii, fig. 5.

[6] Etheridge and Mitchell, *Proc. Linn. Soc. N.S. Wales*, vol. xlii, 1917, p. 503.

anglicus Beyr. (var. *Wenlockensis*[1] and var. *obtusicandatus*[2]) from the Wenlock Limestone, also a variety (*tuberculatus*[3]) of *C. hirsutus* Fletch. from the same formation. All these were based on pygidial characters. A new Wenlock species of *Dicranopeltis* (*D. woodwardi*[4]) was also established on the strength of a well-preserved pygidium.

In the monograph on the Girvan tribolites, the species of *Lichas* named *Geikiei* by Nicholson and Etheridge in 1879 was referred to *Corydocephalus*,[5] but we may place it now in the closely allied subgenus *Euarges*, and another new and completely known species, also from the Drummuck (Up. Bala) Beds, was subsequently described as *Corydocephalus maccullochi*,[6] but it may likewise be put in *Euarges*. The form[7] from the Balclatchie group, which was considered a variety of *L. wesenbergensis* Schmidt in 1906, may now be placed in *Hemiarges* rather than in *Corydocephalus*, but only the pygidium is known.

The trilobites, *L. Libernicus* Portl.[8] and probably *L. ardmillanensis* Reed,[9] respectively occurring in the Stinchar Limestone and Balclatchie group of Girvan, which were ascribed to *Amphilichas*, must now be referred to *Acrolichas* Foerste, as its founder[10] has pointed out.

A new variety, termed *Scoticus*,[11] of the species *Platylichas grayi* Fletcher, was established for a certain form from the Llandovery beds of Girvan, and a head-shield[12] allied to *L. marginatus* Lindstr. was described as belonging to *Metopolichas*, but the characters of the glabella incline me now to put it in the new subgenus *Autolichas* on account of its resemblance to *L. affinis* Ang. A small head-shield[13] from the Drummuck group was compared with *Conolichas æquiloba* Steinh., which is a subgenus otherwise unknown in Britain. From the Dufton Shales of Melmerby the present author in 1907 described a new species as *Homolichas melmerbiensis*,[14] based on a good series of more or less complete specimens, but it belongs to the group in this subgenus having short marginal points to the third pleuræ of the pygidium, and together with others may have to be separated from the subgeneric type and put into a new subgroup.

[1] Reed, Geol. Mag., 1903, p. 3, Pl. I, Fig. 1.
[2] Ibid., p. 3, Pl. I, Fig. 2.
[3] Ibid., p. 7, Pl. I, Fig. 6.
[4] Ibid., p. 9, Pl. I, Figs. 7, 8.
[5] Reed, "Lower Palæoz. Trilob. Girvan": *Palæont. Soc.*, pt. ii, 1903, p. 96, pl. xiii, figs. 14, 14*a*; pl. xiv, fig. 1; pt. iii, 1906, p. 97.
[6] Ibid., Suppl., 1914, p. 28, pl. iv, figs. 9, 10.
[7] Ibid., pt. iii, 1906, p. 98, pl. xiv, fig. 2.
[8] Reed, ibid., pt. iii, p. 106, pl. xv, figs. 1–3; ibid., Suppl., p. 30, pl. v, fig. 2.
[9] Reed, op. cit., Suppl., p. 29, pl. v, fig. 1.
[10] Foerste, *Amer. Journ. Sc.*, xlix, 1920, p. 30, pl. iii, figs. 9*a*, *b*.
[11] Reed, op. cit., pt. iii, p. 100, pl. xiv, figs. 5–10.
[12] Ibid., pt. iii, p. 104, pl. xiv, figs. 15, 16.
[13] Ibid., pt. iii, p. 109, pl. xv, fig. 6.
[14] Reed, Geol. Mag., 1907, pp. 396–400, Pl. XVII.

A small pygidium from the Silurian beds of May Hill has been recently described by the author [1] as a new species, under the name *L. maia*, and by its characters and regularly rounded posterior margin it may be associated with *L. heteroclyta* Barr.[2] It may provisionally be referred to the subgenus *Dicranogmus*, but perhaps should ultimately be put with the Bohemian form in a new subgenus. The cranidium is at present unknown. The new Girvan species from the Mullock Hill beds to be described under the name of *L. silvestris* belongs to the new subgenus *Autolichas* which has been formed for the reception of *L. affinis* and its allies.

With regard to the position of some previously described British species, *L. scutalis* Salt.[3] must be transferred to the genus *Hemiarges*, which is now separated from *Corydocephalus*, and its close resemblance to *H. ambiguus*, which Gürich (op. cit., t. xx, fig. 10) put in this subgenus, is here again worthy of mention. The Devonian species *L. devonianus* Whidb.[4] must be placed in *Euarges* instead of *Corydocephalus*, as Richter (op. cit., p. 59, text-figs. 2*a–c*) has observed.

Notes on some Rock Fragments dredged up between Faroe Bank and Rockall by the Research Vessel S.T. "George Bligh", of the Ministry of Agriculture and Fisheries, during April, 1921.

By J. N. Carruthers, M.Sc., F.G.S., with Contributions by Professor Grenville A. J. Cole, F.R.S., M.R.I.A., and Professor W. J. Sollas, M.A., LL.D., F.R.S.

THE rock fragments described herein were obtained during a cruise of investigation into the fishery possibilities of the Lousy Bank. This Bank, as defined by the 200 fathom line, is some 34 miles long, by 18 miles broad, and lies in a direction E.N.E.–W.S.W. (mag.), being situated between Faroe Bank and Rockall, and having its shallowest portion centred around the position, Lat. 60° 25′ N., Long. 12° 37′ W.

The positions at which the specimens were obtained lie west of Station 13 of the *Triton* 1882 cruise, and north of the *Michael Sars* Station 100 investigated in 1910.

The rock specimens dredged on the respective cruises of H.M.S. *Triton*, H.M.S. *Knight Errant*, and S.S. *Michael Sars* have been described by Peach (1) and (2).[5]

The deposit-samples collected by the S.S. *Michael Sars* have

[1] Reed in Appendix to Gardiner's "Silurian Rocks of May Hill": *Proc. Cottesw. Nat. Field Club*, vol. xx, pt. iii, 1920, p. 219, text-figure on p. 222.

[2] Barrande, op. cit., p. 608, pl. xxviii, figs. 33, 34.

[3] Reed, Geol. Mag., 1901, pp. 5–11, Pl. I, Figs. 1–4.

[4] Whidborne, "Mon. Brit. Dev. Fauna": *Palæont. Soc.*, pt. i, 1888, pl. i, figs. 19, 19*a*, *b*.

[5] Figures in parentheses refer to bibliography at end of paper.

been described by Chumley (3), whilst further valuable accounts of interest in the present connexion are afforded by the well-known work of Forbes (4), and of Cole & Crook (5) and (6).

The material described below is rather meagre, and consists of small pebbles, of which micro-sections were obtained, and the following brief petrological description was drawn up. In the case of the two samples of ooze the writer is entirely indebted to Professors Sollas and Cole for the description, whilst various comments occurring throughout the paper were kindly afforded by Professor Cole. In these cases this fact is indicated.

Slide O—Quartzite.

In ordinary light, almost the whole section is water clear. The constituent quartz grains are both rounded and angular, the two being present in about equal proportion. Peripheral granulation ("mortar structure") is a well-marked feature of the rock, and the granulated material, having collected in interstitial "eyes", has produced the so-called phacoidal structure.

The quartz grains average about 0·25 mm. in diameter. A few of the individual grains are themselves quartzites of crenulate type. Undulose extinction is shown by most of the grains. A fair number of felspar grains is present, these being in the main microcline, though a few small plagioclase individuals occur also.

Slide P—Amphibolite.

This section of a small pebble, about an inch long, is composed for the most part of hornblende occurring in fairly large bladed forms. This mineral shows one well-marked cleavage in most cases, but in one individual, the two characteristic amphibole cleavages at 124 degrees are well developed. Various shades of green are presented, and in certain areas pronounced alteration to chlorite can be seen to have taken place. Some of the hornblende individuals are bent and interpenetrating. Felspar is present as a mosaic of water clear granules, and quartz also occurs in fair amount.

Epidote, zoisite, and sphene are present with faint indications also of the former presence of biotite.

Professor Cole is of the opinion that this amphibolite "is probably an igneous type, and not derived from metamorphosis of mingled types of rock in a granite magma".

Slide Q—Quartzite.

This quartzite consists of fairly large rounded grains, of average size 0·8 mm., cemented in part by granular quartz, but in the main by enlargement. Most grains show strain shadows. Peripheral granulation is visible in places, and the quartz grains are closely interlocked. There are some occurrences of wispy micaceous material in the form of "eyes" where several quartz individuals are in contact; and small patches of some non-resolvable matter which appears to be finely granulated quartz. An interesting

feature of the rock is the richness of the quartz in inclusions. These are very abundant in all the grains, and are disposed along parallel lines which maintain fairly persistent directions. Rows of pores filled with fluid are traceable through contiguous crystals. (Professor Cole styles this rock "Quartzitic Grit.")

Slide R—Arkose.

This rock is considerably ironstained. The quartz grains are for the most part anguiar, many exhibiting undulose extinction. The felspar is mostly microcline, though acid plagioclase is not uncommon (albite).

Grains of perthite are fairly numerous, and granules of ilmenite are distributed throughout the section. The rock is fine grained.

(Professor Cole thinks this rock is derived from a gneiss, and notes a granular, non-isotropic mineral of high refractive index, possibly zircon.)

Slide S—Gneiss.

In this rock the most interesting feature is the presence of parallel veins of quartz traversing the section in a well-marked direction. These veins consist of small grains interlocked in suture fashion. Frayed out patches of biotite occur. Grains of perthite, and of an acid plagioclase are visible, and a comparatively large crystal of microcline also is present. Some of the felspars are bent and fractured. The mica is somewhat chloritized and the quartz grains exhibit undulose extinction.

"Crushed granite, with streaked out bands of quartz. A pressure gneiss of rather fine grain" (G. A. J. C.).

Slide T—Basalt.

This basalt has porphyritic augite and labradorite. Large aggregates of vesicles occur, and a slight development of ophitic structure is visible. The augite is colourless, somewhat idiomorphic, and shows in one case a faint hour-glass structure. Granules of magnetite are very common, small grains of olivine occur, and brown iron oxides are abundant. Many of the felspars have inclusions of the glassy base. There is also present a brown pleochroic rhombic pyroxene in fairly good crystal shape.

"Fine grained olivine-basalt with brownish serpentinized olivine in small grains. Vesicles infilled by green products" (G. A. J. C.).

Slide U—Dolerite.

This rock is a porphyritic dolerite with granular olivine. Large phenocrysts of labradorite and augite occur, and ophitic structure is well shown. The augite is colourless, and some individuals exhibit the two characteristic pyroxene cleavages very clearly. Brown oxides of iron are common, and ilmenite is present in great amount, showing its whitish decomposition product by reflected light.

"Rather recent-looking olivine-basalt, ophitic in part, of the Inner Hebrides type" (G. A. J. C.).

Slide V—Basalt.

This rock is an ophitic basalt, having augite and labradorite both as phenocrysts, and as constituents of the groundmass. Olivine is present as small grains. The felspar has an extinction angle of about 44 degrees measured from the albite laminae. Magnetite, ilmenite, and brown iron ores are abundant as small grains. The most striking feature of the rock is the presence of large aggregates of vesicles, each vesicle being infilled with green products and showing a dark cross between crossed nicols. This rock is considerably decomposed.

"Decomposed fine-grained olivine-basalt. Fibrous and also granular green infillings to vesicles. Much like 'T', and probably from same rock-series" (G. A. J. C.).

Slide W—Albite-Gneiss.

This rock seems to be best described as a coarse-grained albite-gneiss. The quartz grains occurring are closely interlocked, exhibit strain shadows, and are rich in inclusions. The felspars (albite) are much altered, and are occasionally fractured. The rock is very rich in epidote, which mineral occupies a considerable part of the section, being present in some places as a mosaic with quartz. An interesting feature is the presence of a crystal of colourless amphibole with the characteristic cleavages well shown (tremolite ?).

"Gneiss with triclinic felspar, the species of which is not determinable (in the small area of the slide) by symmetrical extinctions. Some beginnings of mylonitization. Epidote has developed in the crevices due to the crushing" (G. A. J. C.).

Slide X—Biotite-Granite.

This is a very much altered rock whose constituent minerals are not easily identified. The minerals occurring are: a greenish biotite, oligoclase, orthoclase, a very little quartz and a large patch of some mineral very much altered and difficult of identification. This mineral had affinities both with felspar and elæolite. Optical tests give an obscure biaxial figure, thus showing it to be orthoclase.

"The well-developed felspathic or felspathoid mineral seems to me biaxial and is thus orthoclase. The sodium-pyroxenes of Judd's 'rockallite' are absent; but the rock, if we had more of it, might prove to be allied to the normal mass of Rockall in containing aegirine. I think, however, we have merely a biotite-granite like those common as intrusions in our British Isles Dalradian series" (G. A. J. C.).

Slides Y and Z are sections of ooze brought up by the snapper lead. After long drying two sections were prepared by Messrs. Lomax. Of these sections Professor Cole states: "Foraminifera (*Globigerina*, etc.) occur in a pale brown matrix, which is, I pre-

sume, calcareous, with terrigenous dark mineral grains." He is of the opinion that the material is *Globigerina* ooze in which some glauconitic infilling has gone on. On treating some of the ooze with hydrochloric acid, Professor Cole obtained numerous ovoid and acicular spicules, and on his advice the two slides and the remaining material were sent to Professor Sollas who very kindly examined them. He noted the presence of sterrasters of a geodine sponge, though in the absence of soft parts its genus was not determinable. Such sterrasters as showed a radiate structure had been attacked, "as all, or almost all sponge spicules brought up in deep sea ooze are, by some solvent agent." This solution, he says, "has developed their radiate structure, and replaced it, in some cases by a mosaic of opal or hyalite, so that a central area or an annular space between centre and circumference of opal is produced. That these sterrasters belong to a geodine sponge is shown by the occurrence, though rare, of triaene and dichotriaene spicules. The prevailing spicules are, however, oxeas, and these are so numerous that at first, before I found the triaenes, I thought we might be dealing with *Placospongia*, which afforded the pseudo-sterrasters to Hinde's *Rhaxella*."

"The sterrasters range from quite young forms to full grown ones. One of the fragments is evidently a piece of the sponge retaining the oxeas, and probably the shafts of some of the triaenes in their natural position, i.e. it is a bit of the original sponge. The oxeas have undergone a considerable amount of solution, by which the axial canal has been greatly enlarged, so that the spicule is converted into a tube with a wide lumen."

Professor Sollas wonders what has become of the dissolved silica, and thinks it has been re-deposited, partly as an almost colourless glauconite. He obtained, after treatment with hydrochloric acid, a granular residue which he took to be silica hydrate. This was disintegrated by NaOH but not completely dissolved. He notes other spicules present in the ooze; an occasional oxytylote, some microscleres, and small oxeas.

Note on the Assemblage by Professor Grenville Cole.

The assemblage of rocks gives one no decisive clue as to the nature of the sea floor over which the dredgings took place. The whole assemblage, however, resembles that occurring in Northern Ireland, where chalk and basalt rest on a Dalradian floor of quartzite, gneiss with included amphibolite or diorite, and mica-schist. The last-named rock does not appear abundantly in dredged material, probably owing to its friability, and it is absent from the present assemblage.

The series of rocks may of course have been included and mingled in the great northern ice-sheet, and thus may show no localization of material such as was revealed (contrary to expectation) off the west of Ireland.

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The Connemara Serpentine Rocks.

By H. B. Cronshaw, B.A., Ph.D.

(WITH PLATE XIX.)

THE serpentine rocks belonging to the metamorphic region of Connemara, West of Ireland, fall into two classes, the ophicalcites and the serpentinized basic igneous rocks.

The existence of exceptionally beautiful pale green and yellow serpentine and variegated ophicalcites is well known. At one time these deposits were quarried at several points, notably at the Lissoughter Quarry near Recess, the Derryclare Quarry on the eastern shores of Derryclare Lough, the Barnaoran Quarry near the head of the Owenglin River which flows into Clifden Bay, and at the Streamstown Quarry situated at the head of Streamstown Bay. There are, however, a number of other localities scattered through the region where small occurrences of ophicalcites and serpentinized igneous rocks are to be found.

In the case of the ophicalcites the serpentine is derived partly from forsterite and partly from tremolite. A locally dolomitized limestone subsequently dedolomitized by metamorphism, followed by hydrolysis of the magnesium silicates through the agency of water vapour set free on solidification of the enormous mass of Galway granite, appears to be the most satisfactory conception of their mode of origin.

Serpentinized basic igneous rocks occur as small masses amongst the schists and gneisses, and in some cases have been brought under the influence of stress action, resulting in massive rocks and schists of the talc-tremolite-anthophyllite type.

It may be mentioned here that a remarkably fine collection of polished slabs of Connemara serpentine rocks is exhibited in the Geological Museum of the University College, Galway.

In a general sense the principal occurrences of ophicalcite show an approximate alignment in an east and west direction which roughly coincides with the main axis of folding as well as with the foliation-strike of the surrounding schists and gneisses. They occur as lenticular masses interfoliated with micaceous schists, quartzites, and amphibole schists, and are distributed along the zone characterized

by the principal, though somewhat sporadic, development of crystalline limestone in the region.

The serpentine rocks exposed at each of the above-mentioned quarries display almost identical features both in the field and when examined under the microscope. They are made up of calcite, serpentine, tremolite, and phlogopite. The calcite occurs as finely crystalline limestone of which the ophicalcite is but a local variation. The serpentine grades from a pale greenish yellow and translucent variety into one which is opaque and almost black in colour. The tremolite is abundantly developed and appears as small bladed crystals which are white or very pale green in colour. Phlogopite may be locally abundant and occurs as light-brown flakes generally possessing a common orientation.

In manner of association these minerals present the most diverse features, and the production of various spotted, banded, and streaked effects is common. Occasionally serpentine may be found in quite large patches which are practically free from other minerals and which vary in colour from pale to dark greenish yellow. More frequently the mineral contains cloudy patches due to the presence of a network of extremely fine thread-like veins of the fibrous variety. However, it is still more usual to find the serpentine intimately associated with tremolite. Generally they are differentiated into irregularly and mostly indefinitely bounded areas with the result that polished slabs present a very attractive appearance. The fine needles of tremolite are crowded together in felted aggregates, although occasionally they form clusters with a tufted, subradiate arrangement. In the latter case the individual crystals are generally larger, due to lack of mutual interference. Again, the serpentine, or that mineral along with tremolite, may be associated with saccharoidal marble as spots and patches, or as alternating bands and streaks frequently folded and contorted. In addition there may be interfoliated brown streaks of phlogopite.

Chemical analysis of the semi-transparent and pale yellowish serpentine, apparently free from inclusions, gave the following result :—

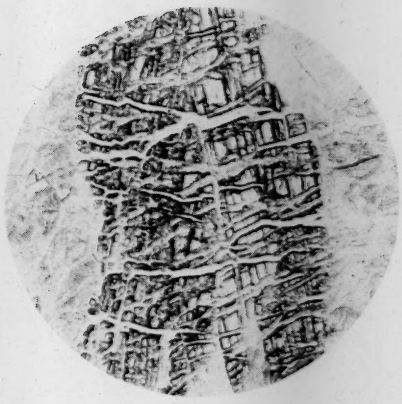
SiO_2 . . .	41·91
Al_2O_3 . . .	1·02
Fe_2O_3 . . .	·98
CaO . . .	·51
MgO . . .	41·70
Ignition loss . .	14·34
	100·46

Pale varieties of serpentine formed from either forsterite or tremolite are practically colourless in thin sections and are generally free from any ferruginous by-products. The olivine-serpentine shows the mesh structure, and relics of the original mineral are sometimes preserved (Plate XIX, Fig. 1).

Thin sections showed all stages in the serpentinization of tremolite.

1

2



3

4

MICRO-SECTIONS OF CONNEMARA SERPENTINES.

[To face p. 468.

Sometimes bladed crystals of tremolite are completely replaced by fibres which are arranged parallel to the principal zone. In these cases the original outlines of the crystals remain clearly defined (Fig. 3).

Polarization tints are low, but, generally speaking, higher than those of the olivine-serpentine. In other cases the change starts along cross-fractures, forming simple or compound veins occupied by fibres which may be slightly curved or somewhat inclined to the walls of the veins (Fig. 2). The latter sometimes pass from one crystal to another and may be sufficiently numerous to cause a complete replacement. Otherwise, the rectangular areas of tremolite enclosed by the cross-veins and crystal boundaries become replaced by a confused aggregate of fibres almost without action upon polarized light. When a rock originally largely composed of tremolite has undergone complete serpentinization a sort of lattice structure is produced by the veins of fibrous serpentine which are crossed by a system of lines marking the original outlines of the crystals. In the case of cross-sections the cleavage directions of the amphibole are thus preserved.

As accessory minerals the ophicalcites contain brown and white mica, apatite, sphene, pyrite, and magnetite.

The geological and mineralogical features of the ophicalcites exposed at Lissoughter, Derryclare, Barnaoran, and Streamstown are practically identical. The Lissoughter Quarry has been opened up in a lenticular mass of crystalline limestone and ophicalcite interfoliated with quartzites, micaceous schists, and plagioclase-hornblende-schists. These rocks have been extensively folded, faulted, and injected with aplite and pegmatite. The exposures at Derryclare are interesting as showing secondary changes in the serpentine.

At places where the cover of peat and gravel has been removed the serpentine is found changed for a depth of some 2 inches to a white and rather porous rock, which has the following composition :

SiO_2 . . .	42·44
Al_2O_3 . . .	4·01
Fe_2O_3 . . .	1·63
CaO . . .	1·07
MgO . . .	36·86
Ignition loss . .	14·71
	100·72

Compared with the adjacent fresh serpentine, the altered material contains more alumina and lime, but less magnesia, and the change has been attended by the precipitation of extremely fine particles of an undeterminable mineral.

The case seems to be one of weathering brought about, possibly, by peaty waters. The Geological Museum in Galway contains specimens of a pseudophite collected from a vein, probably in serpentine, at Barnaoran. The mineral has a waxy appearance and

a hardness of 2. Some specimens are rose-coloured, whilst others are coloured green by inclusions of chlorite. An analysis of the translucent material free from inclusions gave the following results[1]:—

SiO_2 . . .	35·56
Al_2O_3 . . .	24·89
Fe_2O_3 . . .	1·02
MgO . . .	26·02
Ignition loss . .	12·71
	100·20

As mentioned above there are numerous occurrences of serpentine-bearing rocks derived from basic igneous rocks belonging to the metamorphic complex, which is probably of pre-Cambrian age.

Dark green and coarse-grained varieties consist essentially of diallage, associated with a certain amount of serpentine derived from olivine and enstatite. These rocks appear as rounded masses in the areas occupied by acid and intermediate igneous gneisses, and are described more fully by the writer in a paper in course of preparation dealing with the metamorphism of Connemara. Typical examples occur, one at the north-western end of Lough Nahasleam in the Maum district, and the other between Loughaunfree and Lough Aughawoolia. The first consists of diallage, bastite, hornblende, serpentine after olivine, clinozoisite, biotite, iron ores, and an undetermined pseudomorph after felspar. Here diallage formed the dominant constituent. The second has colourless diallagic augite as the principal constituent. Olivine, serpentine, hornblende, carbonates, and iron ores are also present, but in subordinate amounts.

Interfoliated with the sedimentary schists belonging to the same metamorphic complex, are lenticular masses of talc and serpentine-bearing rocks containing tremolite, enstatite, anthophyllite, chlorite, magnetite, green spinel, and carbonates.[2] Evidently they have been subjected to stress action. The rocks are fine grained, and weathered surfaces are deeply pitted and rusty brown in colour. A good example of this type occurs amongst the cordierite-schists which are exposed at the foot of the northern slopes of Cashel Hill. Talc derived from enstatite is the dominant constituent, whilst serpentine, chlorite, iron ores, and carbonates are present as subsidiary minerals.

Another lies in the cordierite-schist on the west side of Lough Agaddy. In this case tremolite is the chief constituent and associated with it are crystals of enstatite traversed by veins of talc. Olivine and green spinel are accessories. There are similar rocks on Cannover Island in Lough Corrib which are interveined with talc developed in unusually large crystals. Under the microscope the

[1] Compare analyses quoted by Flett in "The Geology of the Lizard and Meneage": *Mem. Geol. Surv.*, 1912, p. 144.

[2] Compare the talc-tremolite-anthophyllite described by Flett and Hill in "The Geology of the Lizard and Meneage": *Mem. Geol. Surv.*, 1912.

rocks are resolved into isotropic serpentine constituting a ground-mass for an abundance of talc and magnetite. Some specimens contain well-crystallized magnesite, whilst others show subradiate clusters of anthophyllite (Fig. 4) and serpentine-pseudomorphs, resembling those derived from tremolite (Fig. 3). The long-bladed pseudomorphs are very conspicuous in hand specimens.

The above researches have been aided by a grant from the Dixon Fund of the University of London.

REVIEWS.

GLACIOLOGY: BRITISH (TERRA NOVA) ANTARCTIC EXPEDITION, 1910–13. By C. S. WRIGHT, O.B.E., M.C., M.A., etc., and R. E. PRIESTLEY, M.C., B.A., etc. pp. xx + 487, with 179 text-figures, 291 photograph-reproductions in plates, and 14 maps in cover. Published by Harrison & Sons, Ltd., London, for the Committee of the Captain Scott Antarctic Fund. 1922.

THROUGH the labours of a succession of qualified explorers our knowledge of existing glacial conditions in Arctic and Antarctic regions has increased during the present century by leaps and bounds, or, it might be more appropriate to say, by the hundredweight. The volume before us, issued through the agency of the Scott Memorial Fund, is monumental in every sense. It is not merely the storehouse of the rich harvest of facts regarding ice, gathered during the Scott expedition, but is monographic in scope, revising our previous knowledge and including a radical discussion of the physics of ice and a systematic classification and nomenclature of the protean forms assumed by ice in the mass. The first-named author is mainly responsible for the chapters dealing with the physical aspect; and the second, for the classificatory schemes and for the more strictly geological parts of the work. In all particulars the discussion assumes ample proportions and appeals to the specialist rather than to the general reader, though there is wide interest in the many passages of vivid description, in which the hard conditions of the Antarctic are brought strikingly into view, while the wealth of photographic illustration, besides containing many pictures of great beauty, presents to the eye a complete panorama of ice-forms of every type and in all stages.

To the geologist it is perhaps a little disappointing to find that, after all, he has not got the whole story within these covers, but is referred to future 'Physiographical Memoirs of the Expedition' for the discussion of certain glacial problems in which he may be particularly interested, such as the methods of erosion by ice and the manner of formation of glacial lakes. We shall expect to find there, too, a fuller consideration of the important question, barely touched upon in the present monograph, whether the existing topography of the Antarctic land has been shaped by ice alone, or by ice acting upon a previously waterworn surface. The authors distinguish between "glacierisation — the inundation of land by ice" and "glaciation—the erosive action exercised by land-ice upon the land over which it flows" (p. 134); and the present work is devoted for the most part to the phenomena associated with "glacierisation".

Within our space-limits we can do little more than briefly outline the contents of the volume. The first four chapters are mainly

physical and meteorological, dealing with such matters as air-temperature; solar radiation; atmospheric circulation; precipitation; the classification and mode of development of snow- and ice-crystals; and the mechanics of glacier motion. On the last subject, so fertile in hypotheses, a new idea is promulgated—"It appears to the writers that the fundamental cause of glacier movement in cold regions, where water is never seen except in the immediate neighbourhood of rock, depends on a property analogous and additional to the vapour pressure of ice" (p. 119). The intermolecular exchanges due to this factor are believed to be of prime consequence in bringing about ice-flow under Antarctic conditions.

On another matter, it is interesting to find that the curious 'polygonal structure' assumed by loose rock-detritus lying on gentle slopes or flats, conspicuous in Spitsbergen and other Arctic lands, is strongly developed in the Antarctic also in the rare places where favouring conditions occur (p. 132).

The new classification and nomenclature of land-ice forms proposed in chapter V would no doubt be useful in dispelling ambiguity if generally adopted. The main headings are:—

Type i.—Continental-Ice. Island-Ice. Highland-Ice. Cwm-Ice. Snowdrift-Ice.
,, ii.—Wall-sided Glaciers. Valley Glaciers.
,, iii.—Expanded Foot-Ice. Ice-tongues afloat. Piedmont-Ice. Confluent-Ice. Avalanche-Ice.
,, iv.—Shelf-Ice.

It is hardly to be expected, however, that the application of ordinary descriptive words of this kind can be controlled, or kept in accordance with the authors' definitions, particularly since the types and sub-types mostly tend to merge into one another. The same criticism applies to some subdivisions of the types proposed later. These frequently recurring schemes and tabulations have evidently been very carefully thought out, but they carry the impression of over-elaboration. Even when applied to Land Features, schemes of formal classification have their dangers for the student; and Ice, by its nature, is still less amenable to the method.

However, whether the attempted systematization be approved or not, this part of the book, with its accompanying illustrations, cannot fail to attract the glaciologist by virtue of the illuminating descriptions of the various modes of occurrence of ice, which combine with the details in succeeding chapters to convey a more intimate notion of Antarctic ice-conditions as a whole than has been hitherto available. Of special value is the discussion of the thickness and structure of the Ross Barrier. It is brought out clearly that the Barrier is now fed mainly by the snow which falls or is drifted on to it, and that it owes comparatively little to the influx of the upland glaciers. Acknowledging that the data are insufficient to afford a sure basis for the estimates, the authors, for purposes of calculation,

make certain assumptions which we are very glad to have, since they are the outcome of first-hand knowledge and are likely, at any rate, to be nearer the truth than speculations lacking this quality. It is assumed (p. 217) that the total thickness of the Barrier inland may be 750 ft.; that the average annual excess of precipitation over surface denudation may be equal to 15 ins. of snow of density 0·5; that the average rate of movement at the seaward edge may be 1,500 ft. per year; and that the Barrier may be afloat for a length of 260 miles and a breadth of 320 miles (i.e. over an area much larger than the Irish Sea, but smaller than the North Sea). From calculations on these assumptions it is deduced that the floating sheet probably suffers considerable loss by melting at the under-surface from the action of circulating sea-water. Apart from its present sustentation, the authors consider there is little doubt that the formation of the Barrier in the first place owed much to glaciers protruding as floating tongues into the Ross Sea, and to the growth of fast ice between them.

It may here be noted that the growth of ice-sheets in our shallow British seas during the Glacial period under such conditions would be relatively accelerated by the early stage at which the ice would take ground on the sea-floor (thus excluding the salt-water) and by the curbed discharge due to the restricted sea-fronts narrowing to straits.

In the chapter (VII) on the "Structure of Glaciers" it is observed (p. 224) that one of the most striking features of Antarctic glaciers "is the remarkable paucity of visible rock material either upon their surface, at their sides, or at their ends", and the question is raised whether the Antarctic glaciers have ever performed much work of a rock-grinding and rock-transporting nature. But it is pointed out that the sparsity of visible moraine is accounted for by the large ratio of snow-covered to snow-free land, while ground-moraine and terminal moraines are for the most part beneath the sea and inaccessible to observation. Many peculiarities in the structure of the glaciers are discussed in this chapter, and it concludes with a useful summary of differences between Antarctic and other glaciers.

In dealing with "Ablation and Thaw" (chap. VIII) the authors describe how widely Antarctic conditions differ from those of the other areas of extant glaciation, by reason of the prevalence of low temperatures and high winds. It is shown that in this region the wastage of the surface is brought about mainly by wind and by direct evaporation. "Thaw occurs on a clear surface of ice or snow only locally, and at very infrequent intervals, even in the middle of a normal Antarctic summer" (p. 280). Yet in a few favoured localities, particularly on the Ferrar and Koettlitz glaciers, great temporary rivers of thaw-water were encountered at times; and stress is laid on the strong differential melting noticeable on the flanks of glaciers in the vicinity of bare rock and on ice-surfaces strewn

with any kind of morainic material. This differential melting is undoubtedly always an important factor in glaciation, and must vary greatly with circumstances of exposure and latitude. The low circling sun of high-latitude summers will produce results different in some respects from the discontinuous summer sun of lower latitudes. The aspect of the ground with regard to the sun is a point to be remembered by the student of our British Glacial phenomena.

The Antarctic Ice-foot in all its types is very fully described and illustrated in chap. IX, but the observations in the main serve only to amplify our previous knowledge; and the same remark applies to the next three chapters on Fast-ice, Pack-ice, and Icebergs. In these pages we find, among other things of note, an interesting discussion of frazil-ice as a factor in the under-surface thickening of the sea-ice; a tabulation of all the records to illustrate the varying positions of the pack in Ross Sea, with deductions as to the best method of navigating these waters; and pertinent notes on the difference between the conditions for coast-wise exploration in the Arctic and Antarctic. The authors also take pains to correct the exaggerated notions current as to the height of the great tabular bergs, the highest observed being estimated to rise not more than 160 ft. above sea-level, being thus about the same as the maximum height of the Ross Barrier.

Of peculiar value to the geologist is the chapter (XIII) on Geological Climates of the Antarctic, in which the whole of our present knowledge of Antarctic stratigraphy is summarized and the conditions of ancient sedimentation discussed. The conclusion (p. 444) is accentuated that "*glacial conditions have been the exception and not the rule in Antarctica*". "No evidence yet exists of either a Proterozoic or a Cambrian glaciation [such as has been found now in many parts of the world]. . . . Permo-carboniferous glaciation in Australia, South Africa, and India appears to be represented in the Antarctic only by a desert—possibly semi-frigid—climate. . . ." In the Jurassic period a mild almost tropical climate is indicated, with its flora resembling the contemporaneous flora of Yorkshire, followed by a cooling down to temperate or warm-temperate conditions in the Cretaceous. "Little or nothing is known of the Antarctic climate during Eocene times. In the upper Oligocene and lower Miocene, once more a temperate to sub-tropical flora holds sway over some portion of the Antarctic Continent." In Miocene times, however, the volcanic agglomerates and tuffs entomb erratics which denote the onset of glaciation. It is noted that the question as to how far there was a local or general amelioration in the middle days of this Tertiary Ice-age is not soluble with our present meagre knowledge. Nearer to recent history "we have reason to believe that, in the high level moraines of the Antarctic mainland and in the ice-gouged valleys of the sub-Antarctic islands, we are viewing the remaining evidence of the culmination

of the Antarctic ice-floods which have since been slowly dwindling in size".

The final discussion of the causes and progress of the present "glacierisation" ranges widely over the various physical and cosmological speculations propounded from time to time to explain the past climatal changes, which are mostly too hypothetical to bear the weight of the argument. But the discussion is enriched by many illuminating passages based on personal observations, particularly in respect to the "deglacierisation" at present in progress. Regarding the conditions necessary to initiate and sustain a "glacierisation", it is remarked (p. 454): "One is in fact led to the conclusion that the initiation of a complete snow-covering on a previously bare elevated landmass will profoundly modify the existing air circulation, so as to cause a circulation leading to the formation of a dome-shaped covering such as that observed." Again (p. 469): "One is tempted to speculate on whether the Antarctic Continent, if suddenly freed from ice, would in present conditions remain free from snow, and whether the Ross Barrier, if it were suddenly annihilated, would re-establish itself. We suggest, though it is little more than an expression of opinion, that, in present conditions, the continent would again become snow-covered, but it is very doubtful if the Ross Barrier would grow again to anything like its present dimensions. We do believe, however, that if the Antarctic continent of its present dimensions nowhere reached a height greater than 1,000 ft., it is very doubtful if the present amount of snowfall would permit the *growth* of a permanent ice-covering, either on land or sea."

The authors are to be congratulated on the completion of what must have been a very arduous task, broken as it was by the terrible interval of the War. The volume is well-printed, remarkably free from press-errors, lavishly illustrated, and handsome in every way. The text-figures are on a generous scale and usually very clear, but we found some difficulty in grasping that the three diagrams on p. 153 were intended for bird's-eye views and not for sections like those on the opposite page. The book has no index beyond a bare list of the subheadings to chapters; at the least, an index of the names of places and persons is expected in a volume of this size.

G. W. L.

THE NORTHERN TINFIELDS OF BAUCHI PROVINCE. By J. D. FALCONER and C. RAEBURN, with notes by A. D. N. BAIN and W. RUSS. Geol. Survey of Nigeria, Bulletin No. 4, pp. 67 with 10 plates and 2 coloured maps. Published by the Nigerian Government, 1923.

THE country described in this bulletin, about 5,000 square miles in area, forms a portion of the extensive plain of denudation of the Central Sudan, which is now being again dissected by a re-juvenated river system; the special conditions of weathering

result in a striking development of the Inselberg type of topography, as recently described in this Magazine by Mr. Bain. On the whole it lies at a lower elevation than the Bauchi plateau to the south of it, though traversed by well-marked ranges and groups of hills, mostly composed of a Younger Granite, while the Inselberge are composed of Older Granite and Gneiss. The most interesting rocks belong to the Younger series, and include biotite-granite with riebeckite, various types of syenite and monzonite, with abundant corresponding hypabyssal varieties. In some places the granite contains riebeckite only to the exclusion of biotite. Contrary to the opinion expressed three years ago by Major Williams, the authors maintain that tin is not found in the riebeckite rocks, but only in the biotite varieties. Some very striking examples of intrusion-breccias are described and figured. It is not quite clear why some rocks are called quartz-porphyries and some rhyolites, since all appear to be equally intrusive. The older gneissose granites carry either biotite or hornblende or both. The origin of the tin and the superficial deposits are very briefly described. The mineralization is considered to be due to the intrusion of a great bathylith of Younger Granite, also of Archæan age.

The Nephelite Syenite and Nephelite Porphyry of Beemerville, New Jersey. By M. Aurousseau and H. S. Washington. Journ. Geol., vol. xxx, 1922, pp. 571–86.

After a general review of the literature of the alkali rocks of New Jersey, the authors describe the large mass of nepheline-syenite of Beemerville, which is interpreted as a sill or flat laccolith of foyaite, invaded by dykes of nepheline-porphyry and leucite-tinguaite. It is concluded that these three types are textural and mineral variants of the same undifferentiated magma. The nepheline-porphyry can no longer be regarded as the type of sussexite, though this name should be retained in its original sense. The widespread occurrence of zirconium and rare earths in this area is also discussed.

Sur les détails du relief du terrain houiller couvert par le Crétacique. By Professor J. Cornet. Ann. Soc. géol. Belg., vol. xlv, Bulletin, 1922.

In this brief note Professor Cornet points out that data obtained from borings are seldom accurate enough to give a true picture of the relief of a buried land surface, the effect being on the whole to tone down the irregularities, whereas measurements obtained from mine shafts are exact. Some remarkable examples are quoted of steep slopes on the buried Carboniferous land-surface determined in this way. Thus the two shafts of the well-known colliery of Hensies-Pommereul, between Mons and Tournai, which the reviewer happens to have visited, show a difference of level of 12·20 metres in

a horizontal distance of 75 metres. Still more remarkable is the slope disclosed at the Charbonnage du Nord du Flenu, at Ghlin, where the distance between the shafts is only 20 metres and the difference of level of the base of the Cretaceous is 10·78 metres, a slope of over 1 in 2. It is, therefore, concluded from these and many other instances that the pre-Cretaceous land surface is extremely irregular in detail. These irregularities are regarded as forming a system of ravines due to water action, which sometimes contain isolated patches of Wealden alluvium below the usual and continuous marine Cretaceous.

British Museum (Natural History) Guides.

Guide to the Exhibition Galleries of Geology and Palæontology. pp. 64, with two plates. 1*s.* net.

An Introduction to the Study of Rocks and Guide to the Museum Collection. By the late Sir L. Fletcher. 6th edition, pp. 142. 1*s.* 6*d.*

THE Catalogue of Meteorites in the Mineral Department was recently reviewed in these columns. We have now received two more of the excellent publications describing the collections in the Natural History Museum. The first named gives a general account of the zoological and botanical relations of the organisms preserved as fossils, with special reference to the specimens exhibited in the cases, which are accompanied by many useful models and other aids to a right understanding of their nature. The Stratigraphical and Dynamical series and the Historical Collections are also briefly described.

In the 6th edition of the Study of Rocks very little alteration of the original text has been made, but Mr. Campbell Smith has revised some of the definitions of rock types in accordance with more modern views and the recommendations of the Committee on Petrographical Nomenclature. The pamphlet now forms an excellent introduction to petrology.

OBITUARY.

Madame Christen (Sydney Mary Thompson).

The death of Madame Christen, which took place from heart-failure at Llandudno in July, 1923, will arouse affectionate memories among geologists in all parts of Ireland. Thanks to her wide sympathies, her father's house at Macedon, on the shore of Belfast Lough, became the recognized rendezvous of naturalists. Many members of the Geologists' Association will recall the gathering and the hospitable welcome there in 1895. Inheriting at Macedon a broad and tolerant outlook upon life, Sydney Mary Thompson cultivated tastes ranging from water-colour painting to the study

of both botany and geology in the field. She was an active supporter of the Belfast Naturalists' Field Club, and did much in the organization of winter courses of lectures and practical work dealing with stratigraphy and petrography. Her original observations and records were mostly concerned with the sources of material in the Glacial deposits of Northern Ireland. In 1900 she married M. Rodolphe Christen, a Swiss artist, and she produced after his death, which occurred six years later, a finely illustrated work devoted to his memory (Longmans Green & Co., 1910). In her home, among the hills near Ballater, Madame Christen never lost her interest in geology, and the last of many continental journeys undertaken by her was to the volcanoes of Auvergne in 1922. She died in the fullness of years; but the years to come need spirit and inspiration such as hers.

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Madame Christen: "Investigations into the Glacial Drifts of the North-east of Ireland": *Irish Naturalist*, vol. xi, 1902, p. 275. "A Summary of the [B.N.F.] Club's recent Glacial Work": ibid., vol. xv, 1906, p. 80.

G. A. J. C.

CORRESPONDENCE.

THE BASE OF THE DEVONIAN.

Sir,—Most geologists will, I think, agree that Dr. Stamp has made out a primâ facie case for his correlation of the rocks at the base of the Devonian. Whether the Downtonian and Schistes de Mondrepuits and the other beds correlated with them should be regarded as Silurian or Devonian has still to be determined. The remarkable similarity of the fauna of the Downtonian of Scotland with that of the Old Red Beds that overlie them constitutes a strong point in favour of the view for which he contends. Might not the most satisfactory solution be to regard the strata in dispute as passage beds between the two formations?

I am sorry to see the "Welsh Lake" and "Lake Caledonia" make their reappearance. I thought that it was now agreed that the typical Old Red Sandstone deposits were laid down by streams or short-lived lagoons, usually of a local character.

Is there any reason to suppose that the south-eastern shore line of the Silurian Sea of the Welsh border was continued as an east and west ridge in the neighbourhood of the Bristol Channel? Even if it was, it could not have formed the boundary between the Old Red Sandstone and Devonian types of sedimentation except for a comparatively short period. At the time when the Foreland